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Bank Margins and Profits in a World of Negative Rates

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Abstract

By investigating the influence of negative interest rate policy (NIRP) on bank margins and profitability, this paper identifies country- and bank- specific characteristics that amplify or weaken the effect of NIRP on bank performance. Using a dataset comprising 7,359 banks from 33 OECD member countries over 2012-2016 and a difference-in-differences methodology, we find that bank margins and profits fell in NIRP-adopter countries compared to countries that did not adopt the policy. Moreover, this adverse NIRP effect depends on bank specific-characteristics such as size, funding structure, business models, assets repricing and product – line specialization. The effectiveness of the pass-through mechanism of NIRP can also be affected by the characteristics of a country's banking system, namely, the level of competition and the prevalence of fixed/floating lending rates.

JEL: E43, E44, E52, G21, F34

Keywords: Negative interest rates, bank profitability, NIMs, difference-in-differences estimation, propensity score matching

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1. Introduction

Since the Global Financial Crisis (GFC), policy-makers have been facing a challenging economic situation dominated by economic stagnation, high unemployment and deflation. As an immediate monetary policy response, central banks cut interest rates aggressively through conventional accommodative monetary policies. However, when interest rates approached the zero lower bound (ZLB) without producing the hoped-for effects on nominal spending and inflation, many central banks implemented a range of unconventional monetary policies (UMPs) including large scale asset purchase (LSAPs) in the form of quantitative easing, as well as policy rate forward guidance. UMP took a step further from 2012 onwards when several countries/regions (Denmark, the Euro Area, Hungary, Norway, Sweden, Switzerland and Japan) implemented negative interest rates policy (NIRP) in order to provide further economic stimulus to constantly weak economies (the time of introduction of NIRP is noted in Table 1).

The aim of NIRP is to increase the cost to banks of holding excess reserves at the central bank encouraging them to take them back on the balance sheet (Coeuré, 2016). This should lead to beneficial outcomes for the real economy coming mostly from a greater supply and demand for loans due to the decline in funding costs for both banks and borrowers. Nevertheless, going beyond the barrier determined by the ZLB and pushing rates into "uncharted" negative territory deserves serious consideration and analyses. In this regard, the "how low for how long" question has raised concern about the long-term effect of this policy on financial intermediaries' performance and on the economy as a whole (McAndrews, 2015).

Since interest rates affect both the asset and the liability sides of banks' balance sheet, the effect of NIRP on banks performance is ambiguous (Riksbank, 2016). A cut in interest rates into negative territory may increase bank profitability if: a) there is significant loan growth and margins are not reduced, b) banks boost fee and commission income, c) they hold a sizeable amount of fixed-income securities, d) banks also reduce non-interest expenses, or/and e) negative interest rates improve borrowers' creditworthiness reducing loan-loss provisions. On the other hand, if banks are unable to reduce deposit rates to the same extent as loan rates then margins will be compressed, and if there are limited opportunities to boost non-interest income then profits will likely fall. This will depend also on bank-specific characteristics (size, funding structure, business model, assets repricing and product-line specialisation) as well as the characteristics of a country's banking sector (degree of competition, prevalence of fixed

/floating lending rate)). Banks that rely on wholesale funding may benefit from NIRP in terms of cheaper funding costs compared to those that depend mainly on retail deposits where rates are 'sticky' downward. Similarly, banks with a business model focused on non-interest income (so-called more services oriented) may be less affected by NIRP than banks focusing mostly on traditional intermediation activities. Large banks that have greater international reach, potential to increase lending abroad and more diversified portfolios are better equipped to hedge against interest rate risk and to switch to non-interest focused business models when margins are squeezed. Finally, banks with specific product-line specialisation (such as mortgage lenders) are more likely to be strongly affected by NIRP. Country features such as the degree of banking sector competition, the prevalence of fixed/floating lending rate, as well as a country's current account surplus may also play an important role. Higher bank competition level and fixed lending rate can amplify the contraction of NIMs, and banks operating in countries with sufficient surpluses are likely to hold larger excess reserves subject to NIRP.

The aforementioned factors are essential for the evaluation of NIRP by policy-makers as the pass-through effect of NIRP on bank performance can have profound policy implications in terms of both monetary transmission and financial stability. If NIRP results in a decline in profits, this can erode bank capital bases through a reduction in retained earnings. In turn, this can further limit credit growth stifling NIRP monetary transmission. Low profitability may also raise financial instability concerns especially as many European banks have been struggling to maintain (respectable) levels of profitability because of the slow economic recovery, historically high levels of non-performing loans, and a post GFC and European sovereign debt crisis deleveraging phase. Banks and depositors 'move-into-cash' behaviour could also affect monetary policy transmission and financial stability. If banks hoard cash, this would undermine the effect of NIRP and, consequently, weaken the transmission mechanism. On the other hand, the risk of deposit flight will endanger financial stability by boosting liquidity risk in the banking sector.

We contribute to the existing literature, which typically focuses on low and/or more 'normal' interest rate environments, by investigating, firstly, the impact of NIRP on net interest margins (NIMs) and bank profitability and, secondly, how bank- and country-specific characteristics can amplify or weaken the pass-through effect of NIRP on banks performance. Based on the Euro Area Bank Lending Survey of April of 2016, NIRP hurts bank profitability. Eighty

percent of banks in the survey stated that they expected NIRP to have a negative influence on margins and profits. The result provides further motivation for our investigation into the effects of NIRP on bank performance.

To investigate the impact of NIRP on bank margins and profits we employ a bank-level database comprising 7,352 banks in 33 OECD countries over the period 2012-2016 and a difference-in-differences (DiD) methodology. The DiD methodology enables us to draw conclusions on whether NIRP has squeezed banks' NIMs and profitability in NIRP adopter countries after the implementation of negative rates. Moreover, it permits us to analyse the effectiveness of the pass-through mechanism of NIRP under different macroeconomic and bank-specific environments. Our results show that NIM and return-on-assets (ROAs) demonstrate a strong contraction after NIRP implementation in the treated group, with, on average, a reduction of 12.64% for NIM and 6.29% for ROA. This finding holds well even when we combine DiD with propensity score matching (PSM). Our results also highlight that NIM contraction reduces banks' profitability, despite the case that lower rates can boost bank profits through valuation gains on fixed-income securities (direct) and a reduced cost of non-performing loans (indirect). Finally, the negative effect on profits and margins appears to have been stronger for banks that: are small; have 'interest-oriented' business models; are real estate and mortgage specialists; are well capitalised; lend within national borders; weakly hedge against interest rate risk; operate in competitive systems and where floating loan rates predominate.

The paper proceeds as follow. Section 2 reviews the relevant academic literature. Section 3 introduces our data and methodology. Section 4 presents our results along with several robustness checks and Section 5 concludes.

2. Literature Review and Hypotheses Tests

Our study is based on the literature that analyses the effects of interest rates on bank performance. While there is an extensive literature on the determinants of bank margins and profits that follow the pioneering work of Ho and Saunders (1981), the literature evaluating interest rates, monetary policy and bank performance is still somewhat limited.

One of the first empirical paper dates back to the early 1980s, in which the switch from low to high interest rates determined by the "Volcker doctrine" raised concerns about the soundness and stability of commercial banks and saving and loans associations ("thrift" institutions) that "borrow short and lend long".[2] In this context, Flannery (1981) finds that, while drastic interest rate changes can threaten banking system stability, large U.S. banks mitigate these risks by modifying assets and liabilities positions in order to have matched maturities. Hancock (1985) notes that if monetary policy does not affect the spread between interest earning assets and liabilities, an increase in interest rates tends to boost bank profits. Demirgüç-Kunt and Huizinga (1999) were among the first to investigate the effect of real interest rates on bank margins and profitability. Using cross-country and bank-specific data on margins, they find that high real interest rates are associated with higher NIMs and profitability, especially in emerging economies. English (2002), studying the link between interest rate risk exposure and bank margins in ten OECD countries over the period 1979-1999, points out that the average yield on bank assets is more closely related to long-term rates than the average yield on liabilities, hence a steep yield curve should be associated with higher NIMs. In a similar framework, Albertazzi and Gambacorta (2009) also use information from ten OECD countries over 1981-2003 and aggregate income statement data to show that short-term and long-term rates have a differential influence on bank margins with a more sizeable effect in the long-run. The relation between the slope of the yield curve and bank profitability has been evidenced also by Alessandri and Nelson (2015) with reference to the UK banking sector. Again, their findings suggest that over the long-run (measured using ten-year government bond yields) higher interest rates have an unambiguous positive effect on bank profitability and margins. Busch and Memmel (2017), studying the German market during 'normal' and low interest rate periods, find a small but positive effect of long-term rates on bank margins. However, they state that, during periods of low interest rates, the ZLB constraint on deposit products puts additional stress on banks' margins. Claessens et al. (2018), investigating 47 countries, confirm that low interest rates reduce the ability of banks to be profitable.

Size and business models appear to be key factors that enable banks to hedge against interest rate risk avoiding excessive NIMs and profits volatility in 'normal' operating environments. In this regard, Angbazo (1997) finds that U.S. banks with assets size greater than $1 billion have

[2] Paul Volcker, Chairman of the Federal Reserve during the period 1979-1987, is credited with ending the high level of inflation in the United States by using tight monetary policies and high interest rates.

net interest income that is not sensitive to interest rate volatility, while the opposite is found for small regional banks. Product specialisation, assets composition and size are also found to be important by Hanweck and Ryu (2005). Using a sample of U.S. banks, they underline how small regional banks and mortgage specialists are particularly affected by the volatility of interest rates. Genay and Podjasek (2014) indicate that U.S. banks face decreasing NIMs and returns during periods of low interest rates – and (again) the effect is particularly strong for small institutions. However, they also suggest that the benefits of low rates (in terms of boosting economic activity) outweigh the costs. On the other hand, Covas et al. (2015) show that, during a period of low interest rates (2010-2015 in their sample), NIMs decline more markedly for large U.S. banks (70 basis points against 20 basis points for small banks) because small banks benefit more from a fall in deposit costs.

Empirical analysis of the influence of NIRP on bank margins and profits links to the unconventional monetary policy (UMP) literature. UMP generally includes Quantitative Easing (QE) (large-scale asset purchases) and policy guidance (aimed at managing down long-term interest rate expectations). These policies not only reduce market interest rates but expand and modify the size and composition of both central bank and commercial bank's balance sheets with likely impacts on bank margins and profits. In this regard, Lambert and Ueda (2014), using a sample of U.S. banks over 2007-2012 report a negative relationship between the size of central bank's balance sheet (used as a proxy indicator of QE) and NIMs. Expanding central bank balance sheets alleviate bank funding costs, but the influence is offset by reduced revenues from new loans. Similar results have been displayed by Alessandri and Nelson (2015), who show that Bank of England balance sheet expansion had a negative influence on bank NIMs.

The effect of NIRP is expected to be transmitted via lower money market and bank lending rates to households and corporates (Jobst and Lin, 2016). As previously explained, these lower rates affect both sides of a bank's balance sheet. When lower policy rates are transmitted to bank loan rates, they reduce the value of bank assets. Conversely, lower policy rates also reduce the cost of bank liabilities, namely, lower funding expenses. Heider et al. (2017) find that when policy rates remain positive, deposit rates closely track policy rates. However, when policy rates turn negative, banks that rely on deposit funding are reluctant to reduce deposit rates fearing a loss of their funding base. When downward sticky deposit rates compress lending margins, banks tend to shift activities toward fee-based services. Arteta et al. (2016) suggest

that lending rates generally decline under NIRP, particularly in countries with greater bank competition, but the pass-through effect of NIRP is only partial due to downward rigidities in retail deposit rates.

The extant of earlier literature that investigates the effect of NIRP on bank margins and profitability is still limited. It generally comprises discussions on the possible effects of NIRP on bank performance and overviews of developments in key banking and other financial aggregates in the immediate pre- and post- NIRP periods. In this regard, several papers (Bech and Malkhozov, 2015; Jobst and Lin, 2016; Gross, 2016; Blot and Hubert, 2016; Brunnermeier and Koby, 2016; and IMF, 2017) debate the effect of NIRP on bank profitability without a clear consensus emerging.

In this study, we aim to provide further evidence on the relationship between NIRP and bank margins and profitability. Moreover, we investigate effectiveness of the pass-through mechanism of NIRP under different bank and country – specific features.

2.1 Hypotheses Testing

As aforementioned, earlier literature did not manage to provide a clear conclusion on the relationship between NIRP and bank profitability. There are two main reasons why a negative interest rate environment differs from that characterised by low interest rates (Arseneau, 2017; Eggertsson et al. 2017; Lopez et al. 2018). First, in contrast to a positive interest rate environment, NIRP is subject to the imperfect pass-through of deposit rates as banks are reluctant to impose negative rates on depositors in fear of losing their deposit base (Jobst and Lin, 2016; Demiralp et al. 2017). Second, negative interest rates excessively flatten the yield curve lowering expectations of future economic growth. Both of these effects can amplify NIM contraction in comparison to a positive rate environment because banks cannot reduce deposit rates to the same extent as loan rates and the flattening of the yield curve compresses interest income on long-term maturity assets. In this context, we want to investigate whether negative rates significantly squeezed bank NIMs and profits in NIRP countries. If negative interest rates only have limited pass-through to bank deposit rates (Eggertsson et al. 2017; Lopez et al. 2018) and lending rates closely track policy rates, then the compression of long-term maturity assets combined with downward rigidities on deposit rates will narrow bank margins under NIRP

(Heider et al. 2017). We investigate this point in sections 4.1 and 4.2 of the paper. Our first hypothesis test is as follows:

H1: NIRP has a negative impact on bank margins and profits.

The impact of NIRP on bank profitability can vary according to bank and country – specific characteristics. Given the heterogeneity of banks and countries in our sample, we test the differing effects of NIRP on net interest margins and bank profitability by conducting several sub-sample analyses. As suggested by Bernanke (2016), the effect of NIRP on bank profitability will depend on the sources of bank funding. Banks that depend on retail deposits are more vulnerable as they will find it more difficult to pass negative rates onto depositors. Large banks have more diversified portfolios, greater international reach and hedging expertise; therefore, they can mitigate the effect of NIRP on bank margins and profits by hedging against interest rate risk via derivatives and increasing non-interest income activities (Altavilla et al. 2017; Chaudron, 2018). From a business model perspective, banks with different product-line specialisation tend to exhibit varying degrees of sensitivity to interest rate risk. Hence, banks such as real estate mortgage specialists, that have a higher proportion of long-term assets in their portfolio and face stronger maturity mismatch risk, could suffer a more considerable contraction in profitability induced by NIRP. This will depend also on the contractual details of existing loans and, in particular, their degree of interest rate indexation. Banks that hold mostly floating interest rate loans face stronger compression of NIMs (IMF, 2017). When banks are under-capitalised, the positive effect of NIRP on bank funding cost is limited as banks face difficulties in raising capital. This may have a negative effect on banks' profitability if the decrease in loan rates dominates the reduction of bank funding cost. However, banks that hold capital in excess of that required by regulation face an opportunity cost and profitability pressure as excessive capital could be employed for profitable investment opportunities. Finally, competitive behaviour among banks amplifies their exposure to negative interest rates. If competition between banks is fierce, lending rates should drop, and if deposit rates are already low, then margins will be compressed (Brunnermeier and Koby, 2016). We test the effectiveness of the pass-through mechanism of NIRP under different bank and country – specific features in section 4.3 of the paper. Our second hypothesis is accordingly as follows:

H2: The effect of NIRP on bank margins and profits depends on bank- and country- specific characteristics.

3. Methodology and Data

3.1 Methodology

To capture the effect of NIRP on ROAs and NIMs we use a DiD methodology. This methodology has been widely used in the policy evaluation literature and more recently to banking and financial sector issues (Beck et al., 2010; Calderon and Schaeck., 2013; Berger et al., 2014; Fiordelisi et al., 2017). The advantage of this approach is that it allows for a panel data set-up, which compares a treated group of banks (those impacted by the policy change) with those that are unaffected (the control group or untreated banks). The approach also helps to control for 'omitted variable bias'. For instance, regulatory changes (such as Basel III or the launch of the ECBs Single Supervisory Mechanism) may affect treated and untreated bank performance alike, regardless of the NIRP introduction. However, as these changes may affect banks similarly, the DiD approach avoids this bias by differencing away common trends affecting both groups. Our regression model takes the following form:

$$Y_{ijt} = \alpha + \beta_1\left(Treated_{ij} * Post_{jt}\right) + \beta_2 X_{ijt} + \varphi_t + \gamma_j + \varepsilon_{ijt} \quad (1)$$

Where Y_{ijt} is the NIM (or ROA) of bank *i* in country *j* at time *t*. $Treated_{ij}$ is a dummy variable that takes the value 1 if bank i in country j has been affected by NIRP and 0 otherwise. $Post_{jt}$ is a dummy variable that takes the value 1 after the period that country j at time t decided to implement NIRP and 0 before that period, and β_1 represents the average difference in NIM and ROA between countries that switched to NIRP and countries that did not.[3] X_{ijt} is a vector of bank- and country-specific characteristics to capture cross-bank and cross-country heterogeneity over time that can affect NIMs and ROAs. Bank-specific variables are a combination of balance sheet and performance measures (see next section for a detailed explanation). We also include country specific dummies (γ_j) to control for time-invariant, unobservable characteristics that can shape NIMs and ROAs. We include year fixed effects (φ_t) to control for time-variant shocks over the sample period on bank NIMs and ROAs

[3] The majority of NIRP countries in our sample introduced NIRP in 2014, hence $Post_{jt}$ takes the value 1 from 2014. However, since Sweden, Norway and Switzerland introduced NIRP in 2015 for these the $Post_{jt}$ dummy is set at 2015.

limiting the potential bias in estimates of β_1. All regressions are estimated with bank-level clustering, namely allowing for correlation in the error terms. We use robust standard errors to control for heteroscedasticity and dependence (see Bertrand et al, 2004; Donald and Lang, 2007; Petersen, 2009).

The inclusion of covariates in a DiD framework presents advantages but also disadvantages (Lechner, 2010). On the one hand, introducing explanatory covariates can have the positive advantage of detecting cross-bank and cross-country heterogeneity that can potentially affect bank NIMs and ROAs independently by the introduction of NIRP. On the other hand, the introduction of covariates can cause two main problems. First, when banks are relatively homogeneous in both the treatment and control group, additional covariates can weaken, instead of strengthen, the likelihood that both groups maintain the parallel trend, hence violating our assumption. Second, time varying covariates can change or be influenced by the post-treatment period, leading to endogeneity problems. We assess this problem in three ways. First, we provide statistical tests of mean differences for bank and country covariates between the treated and the control group (Table 1 and Table 2). As displayed, the control variables are, on average, in most cases statistically different between the two groups. Second, we test the control variables for multicollinearity using the *Variance Inflation Factor* (VIF). A mean VIF of 1.07 suggests that our controls are not highly correlated (a correlation matrix is provided in Table A1 in the appendix). Second, to avoid the possibility that time varying control variables can be influenced by the intervention (the NIRP introduction), we test the control variables as dependent variables in the difference-in-differences specification. The test (not reported) suggests that our control variables are not affected by the intervention.

(Insert Table 1 here)

(Insert Table 2 here)

Furthermore, the DiD approach requires that several assumptions hold. First, the control group must constitute a valid counterfactual for the treatment. In order to address this concern, we estimate Pearson correlation coefficients (Table A2 in the Appendix) for three macroeconomic variables (GDP growth, Inflation and Unemployment) in the treatment and control groups. The

significance of coefficients suggests that the countries in the two groups experienced a similar macroeconomic environment confirming the fact that the control group constitutes a valid counterfactual scenario for the treatment. Furthermore, as a robustness check, we combine the difference-in-differences methodology with propensity score matching (PSM) which, by pairing each bank with a control unit, allows us to control for banks having similar characteristics.

Finally, assignment of the treatment has to be exogenous with respect to bank performance. In other words, the policy action ('intervention') should affect bank performance and not vice versa. As pointed out by Couere' (2016), Riksbank (2016) and IMF (2017) the aim of NIRP is "pushing up below-target inflation" or "responding to weak aggregate demand". Increased cost of holding excess reserves at the central bank encourages banks to take them back on the balance sheet to improve loan supply. Hence, influencing bank performance (profits and margins) is not the policy-makers main target but rather a side effect. Moreover, Figure 1 shows that, prior to the introduction of NIRP, NIMs and ROAs moved in a similar direction but the relationship changed thereafter. This is confirmed when we examine the requirement of a 'parallel trend assumption'. According to Bertrand et al. (2004) and Imbens and Wooldridge (2009) the DiD approach is valid only under the restrictive assumption that changes in the outcome variable over time would have been exactly the same in both treatment (countries that experienced NIRP) and control groups (without NIRP) in the absence of the intervention (the introduction of NIRP). Figures 1 depicts the level of NIMs and ROAs from 2011 to 2016 for both NIRP adopter and non-adopter countries. Both NIMs and ROAs move in the same direction in the pre-treatment period (correlation among the treatment and control group is 0.94 and 0.58 for NIM and ROA in the pre-NIRP period, respectively), indicating that the parallel trend assumption holds. Since June 2014, when policy rates in most of the NIRP adopter countries turned negative, NIRP affected banks register lower performance with NIMs falling below 2% in 2014-2015 and below 0.40% for ROAs in 2015 (correlation among the treatment and control group is -0.87 and -0.94 for NIM and ROA in the post-NIRP period, respectively).

(Insert Figure 1 here)

3.2 Data

We rely on Jobst and Lin (2016) for dating the adoption of NIRP regimes and construct a dataset combining information from several sources. The macroeconomic series are from Thomson DataStream, World Bank Databases (World Bank Financial Development Database and World Bank Doing Business Database), Bank for International Settlement Database and ECB Statistical Warehouse Database. Bank balance sheet and performance data are from Orbis Bank Focus and SNL Financial with the aim of maximising the sample size. This also makes it possible to check the consistency of the information provided and to minimise misreporting and outliers. Since Orbis comprises cross-country banks that operate in more than one country, balance sheet data can be either consolidated or unconsolidated. To avoid concerns regarding banks that operate in more than one country in both treated and non-treated groups, we use bank account data that are either unconsolidated (U1 and U2 codes in Orbis) or consolidated but not with an unconsolidated subsidiary. To avoid differences in reporting and accounting conventions, both Orbis Bank Focus and SNL Financial provide standardised bank accounting information. Orbis Bank Focus gives information on whether a company is active or inactive. This allows us to check bank entry and exit status. Accordingly, we drop banks that are or have become inactive over the sample period. We remove also those banks with an annual asset growth higher than 50% to deal with those in substantial mergers and acquisitions activity. Our sample covers 7,352 financial institutions (commercial banks, savings banks, cooperative banks, bank holding companies, finance companies and real estate mortgage specialists) from 33 OECD countries over 2012 - 2016. The sample period is intentionally short. According to Bertrand et al. (2004) and Roberts and Whited (2013), the change in the treatment group should be concentrated around the onset of the treatment. Moving away leads to unobservable and other factors that affect the treatment outcome leading to omitted variables bias and consequently threatening the validity of our model. The treated countries include those of the Euro Area, Hungary, Sweden and Switzerland. Bank balance sheet variables are winsorized at the 1% and 99% level to avoid the influence of outliers.

Descriptive statistics for bank ROAs and NIMs, other bank balance sheet variables, the macroeconomic and institutional variables in the treatment and control groups prior to and after the introduction of NIRP are shown in Tables 1 and 2 (a more detailed explanation of the variables and expected signs are provided in Table A3 in the appendix). Panels A and C of Table 2 display summary statistics of our dependent variables. Following Borio et al. (2015) and Claessens et al. (2018), we define bank net interest margins (NIM) as the difference

between interest earning assets and interest bearing liabilities divided by the amount of interest earning assets. Return on assets (ROA) is calculated by dividing bank's net income by total assets. As shown in Table 2, the mean values of bank ROAs and NIMs for the control group remain constant in the pre and post – NIRP periods. However, for the treatment group the mean values of bank ROAs and NIMs experienced a contraction in the post-NIRP period from 0.47% to 0.40% and from 2.06% to 1.92%, respectively.

Bank balance sheet data. Panels B and D of Table 2 present summary statistics of bank balance sheet data. Bank size (Size) is measured as the logarithm of bank total assets. According to Goddard et al. (2004) and Mirzaei et al. (2013) banks size affects profits positively through the realisation of economies of scale. However, as suggested by Demirgüç-Kunt and Huizinga (1999) and Demirgüç-Kunt et al. (2004) large efficient banks apply lower margins to customers through increasing returns to scale. Therefore, we use Size to control for the impact of economies of scale on bank NIMs and profits. Large banks, with greater international reach, have more potential to increase lending abroad in comparison to small banks that lend mostly within national borders. To investigate this point, we hand collect data on lending outside the Euro area for 116 (*Lending diversification*) significantly supervised entities (SIs) by the ECBs Single Supervisory Mechanism (SSM). We expect large banks with international reach to offset the negative impact of NIRP on net interest margins and profitability. We test this prediction in section 4.3 of the paper.

We employ several variables to control for bank risk aversion, liquidity, credit risk and bank operating efficiency. Several studies (McShane and Sharpe, 1985; Saunders and Schumacher, 2000; Maudos and Fernandez de Guevara, 2004) use the ratio of equity to total assets (*E/TA*) and Tier1 ratio (*Tier1 ratio*) as a proxy for bank risk aversion. A positive relation is expected between this variable and margins as risk averse banks will require higher margins to cover the greater cost of equity (Berger, 1995). We also use liquidity (Carbo and Fernandez, 2007) and a credit risk measure (Carbo and Fernandez, 2007; Poghosyan, 2013; Almarzoqi and Naceur, 2015) to control for bank liquidity and credit risk. In this context, we use the ratio of liquid securities to total assets (Liquidity) and loan-loss provisions to total assets (Credit risk), respectively. We expect that banks with higher liquidity and credit risk to apply a premium to margins. As suggested by Maudos and Fernandez de Guevara (2004) and Maudos and Solis (2009) we measure banks' management efficiency by using the cost-to-income ratio (Cost-to-income), defined as the operating cost that is necessary to generate one unit of income. High

quality management should be reflected in a more profitable assets composition and lower liabilities costs. An increase in this ratio means a decrease in the quality/efficiency of management that will translate into lower margins and profits.

Following Angbazo (1997) and Mirzaei et al. (2013), we use the ratio of off-balance sheet activities on total assets (Off-balance sheet) to take into account the possibility of hedging against interest rate risk. Earlier studies demonstrate a positive relation between bank off-balance sheet size and margins and profits. On the one hand, off-balance sheet instruments lead to higher net interest margins as banks are compensated for increased contingent risk. On the other hand, off-balance sheet items allow banks to expand their assets base thus generating more profits. In section 4.3 of the paper, we conduct a sub-sample analysis where we split the sample to compare the effect of NIRP among banks that strongly hedge against interest rate risk and banks that do not.

In order to control for the impact of bank business models, we employ the variables of bank loan growth (Loan growth), non-interest income on gross revenues (Non-interest income), net fees and commissions on total assets (Fees & commissions), interest income on total assets (Interest income) and interest expenses on total assets (Interest expenses). In section 4.3 of the paper, we use non-interest income and fees & commissions to test whether NIRP motivates banks to switch from a business model that is 'interest oriented' to one that is more 'service oriented' (Altavilla et al. 2017). As shown in Table 2, the mean value of Loan growth improved in the post-NIRP period for the control group from 6.35% to 8.63%. At the same time, the ratios on Non-interest income, Fees & commissions, Interest income and Interest expenses remain constant in the post-NIRP period for the control group. However, for the treatment group, the mean value of Loan growth fell from 3.58% to 3.32% in the post-NIRP period. Alongside, the mean value on Interest income declined from 3.02% to 2.55% for the treatment group in the post-NIRP period. The mean values on Non-interest income and Fees & commissions improved from 35.72% to 37.48% and from 0.77% to 0.80%, respectively, indicating that banks in the treatment group moved to a more service- oriented business model in the post-NIRP period. In a robustness check in section 4.4 of the paper, we check for the different effects that NIRP may have on interest income and interest expenses by including them as dependent variables in the regression model.

Country level controls. Table 1 displays the country-specific variables including: macroeconomic performance indicators; measures of banking sector competition; proxies for other UMP instruments; and a variable that shows whether floating or fixed interest rates are more prevalent in respective countries. We first employ GDP growth (GDP growth), consumer price inflation (Inflation), the sovereign bond yield (Yield curve) and the size of credit in the economy (Credit-to-GDP) as measures of macroeconomic conditions. Athanasouglu et al. (2008) recognise a twofold GDP growth effect on bank performance. On the one hand, GDP growth has a positive effect on bank profits coming from a greater demand for loans. In contrast, there may be a negative relationship if the supply of funds (deposits) declines due to a rise in consumption in-line with GDP growth. The extended literature (Molyneux and Thornton, 1992; Boyd et al, 2001; Demirgüç-Kunt et al, 2004; Gelos, 2006; Almarzoqi and Naceur, 2015) has also demonstrated a positive relationship between nominal inflation and bank margins and profits. Since several studies underline the positive relation between the expectation of interest rates and net interest margins and profitability, we also control for the slope of the yield curve by using the 10-year government bond return. Finally, to capture the importance of bank credit in the economy we include the loan volume to GDP ratio.

As other UMPs, including central bank asset purchase programs (Di Maggio et. al, 2016; Kandrac and Schulsche, 2016; Rodnyanski and Darmouni, 2017; Chakraborty et. al, 2017), were conducted at the same time as NIRP, we include variables to account for these effects. In-line with Gambacorta et al. (2014), Lambert and Ueda (2014), and Alessandri and Nelson (2015) we employ the logarithm growth rate of a country's central bank balance sheet *(CB_GR)*. We also use the logarithm growth rate of the monetary base *(M0_GR)* as a further control to isolate the impact of other UMP's on bank NIMs and ROAs.

Bank profitability and margins may also be driven by banking sector competition. Following Maudos and Fernandez de Guevara (2004), Carbo and Fernandez (2007), Hawtrey and Liang (2008), Lepetit et al. (2008), Maudos and Solis (2009), Almarzoqi and Naceur (2015) and Entrop et al. (2015), we use the Lerner index (Lerner index) to control for competition in the banking sector. The Lerner index is the difference between the price and the total marginal cost as a proportion of the price of banking services and is taken from the World Bank Global Financial Development Database. It ranges between 0 (perfect competition) and 1 (monopoly). NIRP is expected to have a stronger impact in more competitive banking markets as changes in policy rates are likely to be passed on more effectively.

We also try to disentangle the impact of NIRP on bank margins and profitability in those countries that for historical or cultural reasons have a preference for lending at a floating or fixed rate basis. We define floating rate countries are those that have a share of variable rate loans to total loans greater than 63% (median), and vice versa for fixed-rate countries. One would expect the impact of NIRP to be greater in countries where floating rates are more prevalent. Following Albertazzi and Gambacorta (2009) we address this issue by using the share of variable rate loans in total loans to households and non-financial corporations (floating-fixed rate) taken from the ECB Statistical Warehouse.

Finally, in section 4.4 of the paper, we test the different elasticity of deposit rates and loan rates to NIRP. Following Carbo and Fernandez (2007), we define the price of loans as the ratio of gross interest income on loans (Loans rate) and the price of deposits as the ratio of interest expenses on deposits (Deposits rate).

Further institutional controls. Table 1 presents also further institutional controls relating to: total bank reserves (Reserves); taxation (Taxation); depth of credit information (Depth credit info); and legal and investors' rights (Legal rights). Extensive is the literature that takes the ratio of cash and balances at the central bank on total assets to capture both the regulatory requirement and the opportunity cost of banks to hold less-than-market remunerated reserves at the central bank (Demirgüç-Kunt and Huizinga., 1999; Angbazo, 1997, Maudos and Fernandez de Guevara, 2004; Gelos, 2006; Maudos and Solis, 2009; Almarzoqi and Naceur, 2015). The effect of bank reserves on profitability and margins could be either positive or negative. The relation may be negative as under-remunerated reserves lower net interest income and profitability. Alternatively, if banks pass the cost of reserves onto bank customers, we should expect a positive relationship.

We also include the ratio of taxes on operating income (Demirgüç-Kunt and Huizinga., 1999; Gelos., 2006) to take into account the direct effect of corporate income taxes on bank margins and profits, as banks may try to pass through increases in corporate income taxes to bank customers. In-line with Gelos (2006) and Almarzoqi and Naceur (2015), we also use a depth of credit information index that measures rules affecting the scope, accessibility and quality of credit information available through public or private credit registries. The index ranges from 0 to 8, with higher values indicating the availability of more credit information (from either a

public registry or a private bureau) to facilitate lending decisions. Banks are likely to require higher margins if credit information is poor. Finally, we control for the strength of legal rights (Demirgüç-Kunt and Huizinga., 1999; Gelos., 2006; Poghosyan., 2013; Almarzoqi and Naceur, 2015). The legal rights index ranges from 0 to 12 and measures the degree to which collateral and bankruptcy law protect the rights of lenders. The higher the score the stronger the legal protection in a certain country. We expect that weak contract enforcement and inefficient collateral reconciliation may prompt banks and investors to require higher margins and profits to compensate for the additional risk.

4 Empirical results

4.1 Baseline results

Our baseline results from estimating equation (1) are presented in Tables 3. Our main interest is the size, sign and statistical significance of the coefficient of β_1 that represents the average difference in the change of NIMs and ROAs between countries that adopted NIRP and those that did not, denoted in the table as the *NIRP-effect*. In the regression results denoted as Table 3, the coefficients of *NIRP-effect* are sizeable, negative and statistically significant at the 1% and 5% level for NIMs and ROAs, respectively. Countries where central banks implemented NIRP experienced a decline in NIMs and ROAs of 16.41% and 3.06%, respectively, compared to countries that did not adopt NIRP. In-line with expectations, the size of the coefficient on NIMs is larger than that of ROAs. Overall, this result is consistent with the hypothesis that NIRP has a negative impact on bank margins and profits. It also indicates that the contraction in NIMs (as a key component of bank profitability) indirectly drags down bank ROAs but to a lesser extent – a fall in margins reduces profits but not to the same extent as the overall effect is likely mitigated by higher non-interest income (via increased fees and commissions, security valuations, trading income and such like).[4]

(Insert Table 3)

[4] We test this hypothesis in the following section of the paper.

The covariates are mostly significant at conventional levels with signs in-line with the literature on the determinants of NIMs and ROAs. Size is mostly negative and statistically significant for NIMs suggesting that small banks have lower margins than their larger counterparts. The E/TA variable is positively correlated to both NIMs and ROAs implying that less leveraged banks register higher margins and profits. In contrast, Liquidity is negatively related to both NIMs and ROAs revealing that banks that are less liquid apply higher margins to compensate for greater risks. The control variable of Loan growth is positively related to both NIMs and ROAs showing that lending volume is a strong determinant of bank margins and profits. In contrast, the Cost-to-Income ratio displays a negative relationship to both the dependent variables. Efficient management translates into higher margins and profits. As expected, Credit risk is positively correlated with NIMs and negatively with ROAs. On one hand, banks with large non-performing assets apply higher margins to compensate for the excessive risk. On the other hand, banks with deteriorating loan quality in their balance sheets face lower profitability. Among the macroeconomic variables, Inflation displays a strong positive coefficient for both NIMs and ROAs suggesting that the low inflation decade since the GFC is another factor affecting banking sector performance. Depth of credit also illustrates a significant negative relation with NIMs. Poor credit information results in higher margins required by banks. Credit-to-GDP is negatively related with NIMs indicating that banks operating in countries with less developed financial sectors apply higher margins. As expected, the Yield curve is positively related with NIMs. This result is in-line with the literature examined in section 2. Finally, Taxation is positive for both NIMs and ROAs suggesting that banks that pay higher taxes pass through corporate income taxes to bank customers.

4.2. Propensity Score Matching – Difference-in-Differences

As previously described, one of the difference-in-differences assumptions requires that the control group must constitute a valid counterfactual for the treatment. Although we provide evidence (section 3.1) that both the treatment and the control group experience a similar macroeconomic environment in the years following the financial crisis, we further test this assumption by constructing a control sample using propensity score matching (PSM) as proposed by Rosenbaum and Rubin (1983). The predicted probability (propensity score) of NIRP to be undertaken by a country is obtained from the estimation of a Probit model. We use

macroeconomic variables (GDP and the inflation rate) to match banks operating in NIRP adopter and non-adopter countries. Furthermore, to make sure that the propensity score predicted from the Probit model is successful in controlling for bank-specific differences between treated and the comparison group in the pre-NIRP period, we include bank size, equity strength, and lending growth in the propensity score estimation. The propensity score matching model can be represented as follow:

$$p_i = \Pr(D_i = 1 | X_{ijt}) = \delta(X_{ijt}^{'}\beta + \varepsilon_i) \quad (2)$$

where D_i is a dummy variable describing the treatment status. D=1 if the bank has been affected by the policy, and D=0 otherwise. X_{ijt} is a vector of observable macroeconomic variables and bank characteristics in the two years prior to NIRP and δ is a standard normal cumulative distribution function. Specifically, we implement kernel matching (Heckman et al. 1998) with weighted averages of all the banks in the control group to construct the counterfactual outcome. The advantage of using Kernel matching is the relatively smaller variances resulting from the fact that more information is used in the estimation. The results from the Probit model, used to generate propensity scores of being affected by NIRP, are presented in Table 4. As displayed, the majority of the covariates are significant at the 1% level suggesting that banks operating in countries with weaker economic prospects (represented by lower GDP growth (GDP growth) and low inflation (Inflation)) have a greater probability of being affected by the negative interest rate policy. Moreover, countries with banks that are small (Size), with lower loan growth (Loan growth) and that are less capitalised (E/TA) tend to have a higher probability to be the target of NIRP.

(Insert Table 4 here)

The results from the PSM matching difference-in-differences estimations are presented in Table 5. As shown, matched banks NIMs and ROAs display a sizeable and statistically significant contraction after NIRP providing further evidence on the reliability of the baseline estimates.

(Insert Table 5 here)

4.3 NIRP Results Based on Bank and Country Sub-Sample Analyses[5]

As suggested by Bech and Malkhozov (2015), Jobst and Lin (2016), Arteta et al. (2016), Brunnermeier and Koby (2016) and IMF (2017), the contraction in NIMs and erosion of profitability should be more marked for small banks operating in competitive markets. We also expect the influence of NIRP to vary for banks with specific product-line specialisations and that operate in countries where floating rate assets are more prevalent. If competition from other banks is sufficient, lending rates should decrease, and if deposit rates are already low, then margins will be compressed. This effect should be stronger for small retail banks relying on deposits as a source of funding. Banks that hold mostly floating interest rate loans face stronger compression of NIMs as lending rates for new loans decline and existing (variable-rate) loans re-price while deposit rates remain sticky-downward. Also banks with a specific product line specialisation (such as real estate mortgages) that have a higher portion of long-term assets in their portfolio (facing stronger maturity mismatch risk), should also be more highly affected by NIRP. In contrast, large banks with a more diversified business model, greater potential to increase lending in NIRP non-affected countries and stronger interest rate risk hedging behaviour will be able to anticipate the reduction of net interest margins by: increasing non-interest income via fees and commissions; increasing net interest income by lending in monetary regimes not affected by NIRP; and using derivatives to hedge against interest rate risk. In the following sections, we focus on the role of bank size, bank business model, market competition, asset interest rate composition, capitalisation and bank specialisation.

4.3.1 NIRP and Bank Size

[5] Beside the subsample analyses conducted in this section of the paper, various others have been carried out. Specifically, we investigate the effect of NIRP on: countries in surplus/deficits; where there is different bank activity restrictions; for various types of bank risk-taking and also on government owned banks. Although not reported, these results are available upon request.

First, we examine the impact of NIRP on NIMs and ROAs by running percentile regressions based on size.[6] The results reported in Table 6 can be summarised as follows. First, the largest banks show a statistically insignificant contraction in margins (panel A in Column 1) in comparison to the smallest banks that display a compression in margins of 17.83% (Panel A in Column 7). Second, NIRP positively affects large bank profitability as demonstrated by the statistical significance of the coefficient (Panel B in Column 2). Following dell'Ariccia et al. (2010), this result suggests that NIRP enables large wholesale funded banks to take greater advantage of declining funding costs partially offsetting pressure on margins and profitability. Second, the coefficients get larger in magnitude as bank size shrinks. This is consistent with the literature mentioned in Section 1 indicating that large banks, through hedging and lending and income diversification, are better able to protect themselves against interest rate risk.

(Insert Table 6 here)

To gain further insights into these large bank behaviours, we investigate whether diversification opportunities allows the largest banks to anticipate the reduction in net interest margins by shifting towards a more service orientated business model. Table 7 (Panel A and B) shows the estimates based on bank size for the impact on non-interest income (NII) and fees and commissions income (FEE). The results confirm the hypothesis that the large banks adapt their business model according to the monetary policy environment and increase non-interest income and fees and commission income.

(Insert Table 7 here)

4.3.2 NIRP and Bank Business Model

Furthermore, we test whether banks that strongly hedge against interest rate risk are less affected by NIRP. We use the ratio of off-balance sheet items (OBS) on total assets and split the sample according to the median level of OBS, defining as the sub-sample of strongly

[6] We define banks in the first percentile as having an asset size smaller than $300 million. Banks in the second percentile with an asset size between $300 million and $1 billion. Banks in the third percentile an asset size between $1 and $4 billion. Banks in the last percentile with an asset size larger than $4 billion.

hedged banks with more than 6% of off-balance sheet to total assets ratio, vice versa for the group of weakly-hedged. The assumption is that the larger the amount of OBS items the more likely that interest rate risk will be hedged. The results are displayed in Table 8 (Panel A). As expected and in-line with recent papers investigating the low interest rate environment on interest rate risk (Chaudron, 2018), we find that large banks with substantial off-balance sheet activities are likely to hedge against interest rate risk more effectively – they display lower net interest margin contraction as well as higher ROAs (although not statistically significant).

In Panel B of Table 8, we test whether large banks with greater international reach and potential to increase lending abroad offset the negative impact of NIRP on bank margins and profitability by diversifying lending in monetary regimes unaffected by negative interest rates. For this test, we hand collect data on lending inside and outside the Euro area for 116 significantly supervised entities (SIs) regulated by the ECBs Single Supervisory Mechanism (SSM). We reckon SIs represent a suitable sample as these banks operate globally and therefore have substantial lending diversification opportunities. To match the SIs with suitable banks belonging to the control group, we apply the nearest neighbour PSM approach. Specifically, we match control group banks that have size and lending similar to the SIs treatment group. Once again, the results suggest that large banks did not face a reduction of net interest margins and return on assets after NIRP when compared with a control group of banks with similar characteristics. This is also in-line with Altavilla et al. (2017) who employ a sample of 288 large European banks and did not find any effect of the low interest rate environment on bank profitability. This result has also important policy implications in terms of financial stability. Since the effect on SI banks is small and not statistically significant, it is therefore less critical for financial stability purposes.

4.3.3 NIRP and Banking Sector Competition

In Panel C of Table 8, we assess the impact of NIRP in the context of competitive conditions in banking markets. In this case, we use the Lerner index as a proxy for competitive conditions.[7] Sørensen and Werner (2006) argue that banks operating in a less competitive environment make slower adjustments to interest rates (and therefore to NIMs), which slows the

[7] For this exercise, similar tests were also undertaken using the Boone index and the Herfindahl-Hirschman Index (HHI). The results (not reported but available upon request) are similar to those using the Lerner index.

transmission of monetary policy. Brunnermeier and Koby (2016) present a "reversal interest rate" hypothesis according to which there is a rate of interest at which accommodative monetary policy "reverses" its effect and becomes contractionary. They show that low interest policy is likely to have a more limiting effect on bank lending in competitive markets because of the associated pressure on NIMs. As the Lerner index varies between 0 and 1, we split the sample according to the median of the Lerner index, defining as more-competitive those banking sectors with a Lerner index below 0.24, and vice versa for less-competitive. The results, reported in Panel C of Table 8 confirm our hypothesis and support the aforementioned studies: namely that the impact of NIRP on bank profits and margins in competitive markets is negative and statistically significant. In less competitive markets in contrast, the impact of NIRP is negative but statistically insignificant for NIM while positive and statistically significant for ROA suggesting that banks here are better able to maintain profitability as they face less competition and downward lending rates pressure.

4.3.4 NIRP and Fixed/Floating Lending Rate Countries

In Panel D of Table 8, we try to disentangle the effect of NIRP for floating-rate and fixed-rate countries. According to Albertazzi and Gambacorta (2009), Jobst and Lin (2016) and Brunnermeier and Koby (2016), the impact of NIRP should have a greater effect on variable-rate loans and on new loans. Hence, banks having a higher proportion of outstanding floating rate loans/assets should be strongly adversely affected by the new monetary regime compared to those that rely more on fixed rate assets. The ECB's Statistical Warehouse provides data on the share of variable rate loans in total loans to households and non-financial corporations. Again, we split the sample dividing the treatment group into floating and fixed rate countries according to the median (see Table 2 for a list of floating and fixed rate countries). For this exercise, we consider a floating rate country as having a share of variable rate loans to total loans greater than 63%, and vice versa for fixed-rate countries. The results confirm a negative and significant relationship between NIRP and NIM in countries where floating loan rates prevail. In countries with a high percentage of fixed loan rates, NIRP boosted ROA by cutting bank funding cost without diminishing the lending rate.

4.3.5 NIRP and Bank Capitalisation

As a further test, we investigate whether negative interest rates have a diverse effect depending on the level of bank capitalisation. When banks have little capital, the increase in the cost of funding can dominate increases in loan rates as banks face difficulties in raising capital. In such a scenario, NIRP should have a greater effect on banks that are less capitalised. However, it is also true that banks that hold capital in excess of that required by regulations face an opportunity cost and profitability pressure as excessive capital could be employed for profitable investment opportunities. In our sample banks are, on average, well-capitalised (the median level is 14.37%). When we split the sample according to the median level of capital (using the Tier1 ratio), we discover that banks with lower capital ratios keep-up profitability to mitigate the negative impact of negative rates on net interest margins and profits. Banks that are well capitalised suffered more from NIRP. This result is shown in Panel E of Table 8. This result adds also to the ongoing debate on the benefits and costs of bank capital under tight macro prudential policies.

(Insert Table 8 here)

4.3.6 NIRP and Bank Product-line Specialisation

As a final test, we try to capture differences in bank specialisation. As suggested by Hanweck and Ryu (2005) banks with different product-line specialisations tend to have distinctive business models and consequently they exhibit varying degrees of sensitivity to interest rate risk. The magnitude of this effect depends on the composition and repricing of existing assets and liabilities. Banks that have a higher proportion of net long-term assets in their portfolios should experience a greater contraction in their NIMs as interest rates decline. Accordingly, we divide the sample into different bank types (bank holding companies, commercial banks, cooperative banks, finance companies, real estate mortgage specialists and savings banks) relying on the classification provided by Orbis Bank Focus. The results are displayed in Table 9 (Panels A and B). As expected, real estate mortgage specialists and finance companies face strong NIM and ROA compression after the introduction of negative rates in comparison with the control group. The results demonstrate a similar negative and significant effect of NIRP on the performance of commercial banks, cooperative banks and saving banks. This negative and significant effect disappears in the group of bank holding companies, which is in-line with our previous results on bank size, income and lending diversification.

(Insert Table 9 here)

4.4 Further Robustness Checks

4.4.1 Lending Rates, Deposit Rates, Interest Income and Interest Expense

NIRP induces reductions in interest rates to motivate banks to run down their excess reserve balances. However, since deposits (may) have a "price floor" set at zero, a decline in lending rates can lead to a contraction in NIMs.[8] We control for this effect by including in our analysis both lending rate and deposit rates. The results are reported in Panel A of Table 10 (columns 1-2). As expected, Loans rate displays a strong positive relation to NIMs (column 1) suggesting that higher interest rates on lending are associated with high net interest margins. In contrast, Deposits rate has negative sign (column 1) indicating that lower deposit rates allow banks to benefit from reduced funding costs. The coefficients between NIM and NIRP retain their significance level with magnitudes in-line with the baseline regressions. The significance of the coefficients between ROA and NIRP drops-off due to the fact that a narrowed NIM will motivate banks to compensate the loss by focusing on fee and commission income. In order to identify the individual effect of lending and deposit rates on bank performance we employ Interest income and Interest expenses as dependent variables in our econometric specifications. The results reported in Panel A of Table 10 (columns 3-4) confirm a negative and significant effect of NIRP on both interest expense and interest income. However, the larger magnitude of the interest income coefficient supports the hypothesis that NIRP has a bigger effect on interest income as deposit rates are sticky downward. Most banks have not passed on the negative interest rates to their customers. Banks that rely on deposits are reluctant to reduce rates, fearing the loss of their funding base. It appears that the mismatch between sticky deposit rates and competitive loan rates diminishes bank interest income more than the beneficial effect of NIRP on interest expenses in terms of reduced wholesale funding costs.

4.4.2 Other Unconventional Monetary Policy

[8] However, as explained in the previous section, in countries like Sweden and Denmark, where banks operate in a highly concentrated banking system they may find it easier to lower retail deposit rates below zero.

NIRP was brought into the UMP mix by central banks several years after the adoption of other UMPs, and in particular, the extensive use of outright asset purchases via QE. It is important to disentangle the effects of NIRP on profitability and margins from the effects of these policies. Outright asset purchases were aimed at expanding the central bank's balance sheet to increase the level of the monetary base, encouraging banks to lend – in order (ultimately) to boost nominal spending (Bernanke and Reinhart, 2004). Accordingly, we proxy for the use of other UMPs by including, alternatively, variables that take into account the central bank balance sheet size and (alternatively) the size of the monetary base. The results reported in Panel B of Table 10 (columns 1-4) are in-line with the studies of Lambert and Ueda (2014) and Alessandri and Nelson (2015) underlining the possible negative effect of UMP on margins.[9] However, unlike NIRP, other UMP improved bank profitability measured by ROA by facilitating higher credit supply and better funding conditions. In contrast, the results of NIRP confirm that negative rates have squeezed both bank margins and profitability.

4.4.3 Splitting the Sample at the European Level and Removing Countries that introduced NIRP in 2015.

As further robustness checks, we alter our country sample in two ways. Firstly, we focus only on European countries where the treatment group includes only European NIRP adopters and the control group includes only European non-NIRP adopters. Second, we remove late NIRP –adopter countries, namely Switzerland (adoption in January 2015), Norway (September 2015) and Sweden (February 2015) to see whether the results hold. Splitting the sample in multiple control and treatment groups helps also to reduce biases and unobservable variables associated with just one comparison. These results are reported in Panels C and D of Table 10 (columns 1 to 4). The coefficients of NIRP in both cases remain negative and statistically significant.

[9]It might be the case that both UMPs and NIRP have a positive impact on non-interest income that could offset the negative effects of declines in NIM on profitability. We complement the analysis of the non-interest income baseline regression by adding M0_growth as a UMP control. The result (not reported) shows that both NIRP and UMPs affect positively non-interest income. However, the overall negative effect on ROA displayed in the baseline regression indicates that the negative effects of NIMs on bank profits outweigh the positive effect of greater non-interest income and so profitability still falls. This last point has been further examined in section 4.3 (Table 7) and is driven by the fact that small banks did not manage to increase non-interest income via fees and commissions.

4.4.4 Placebo Tests

We report two final robustness checks. First, we try to eliminate the possibility that bank margins and profitability in the treatment group may have altered prior to the introduction of NIRP—for example, in anticipation of the adverse effects of NIRP, or for some bank-specific reasons—thereby invalidating our choice of DiD estimation. If the estimated coefficients on the 'false' NIRP are not statistically significant, we can be more confident that our baseline coefficient is capturing a genuine monetary policy shock. Moreover, it allows us to control for the difference between low and negative interest rate environments. In Panel E of Table 10 we report results from estimates in which we extend our sample to the period from 2011 – 2014 setting the introduction of a "fake" NIRP in 2013. The coefficient on the NIRP variable is still negative but smaller and not statistically significant adding further support to the validity of our baseline estimation. Second, our research question is to investigate whether bank- and country-specific characteristics amplify or ease the effect of NIRP on bank performance. However, banks in each country are heterogeneous and they can be affected differently by NIRP. Hence, at an aggregate level, there can be a neutral overall effect as banks that suffer from the introduction of NIRP counterbalance those that benefit from the policy. If we do not find any significant relationship between NIRP and margins and profits at the aggregate level, we can be more confident that our results are driven by bank-specific characteristics. The results in Panel F of Table 10 strengthen our findings. The NIRP-effect is not significant when we conduct cross-country comparisons by averaging banks in each country to document aggregate effects. This provides further evidence that the effect of NIRP depends on the aforementioned bank-specific features.

(Insert Table 10 here)

5. Conclusions and Policy Implications

Since 2012, several central banks have adopted NIRP aimed at boosting real spending by facilitating an increase in the supply of bank loans. The policy has generated controversy with skeptics pointing to several factors that might affect the soundness of financial institutions and complicate the transmission from negative policy rates to higher bank lending. One factor that

has been mentioned is that NIRP could compress NIMs and, therefore, bank profits, which may erode bank capital bases via a reduction in retained earnings posing financial instability concerns. Reduced retained earnings and the subsequent erosion of bank capital may also limit the transmission of NIRP to bank lending as retained earnings are the most important source of bank's own funds (Shin., 2016). This creates a vicious circle where squeezed margins and low profits limit bank's ability to retain earnings and build capital buffers ultimately increasing risks as well as stifling NIRP monetary transmission.

In this paper, we provide new evidence that bank margins and profitability fared worse in NIRP-adopter countries than in countries that did not adopt the policy. Specifically, countries in which central banks implemented NIRP experienced a decline in NIMs and ROAs of 16.41% and 3.06%, respectively, compared to those countries in which central banks did not follow this policy. Furthermore, our evidence points also to a dichotomy between non-binding monetary policy goals and binding capital requirements. This suggests a policy coordination dilemma where NIRP tries to boost lending growth at a time when prudential requirements force banks to hold greater amount of higher quality capital and liquidity.

Our findings also show that the effect of NIRP on margins and profitability depends upon bank- and country-specific factors. For instance, large banks are able to mitigate the negative effect of NIRP on NIMs and ROAs through hedging, lending diversification and by switching from interest to non-interest oriented business models. Consequently, small banks appear to be more affected by the policy. Among country-specific factors we find NIRP to have a stronger adverse effect on bank profitability in competitive banking sectors and in countries where floating interest rates predominate. These results hold and are robust to the inclusion of a wide range of bank-specific, institutional and macroeconomic control variables. They also stand-up in the face of a broad range of robustness checks, including controlling for the effects of lending and deposits rates, other forms of unconventional monetary policy, sub-sample analysis, aggregate effects, and to (possible) changes prior to the introduction of NIRP. Overall, the adverse impact of NIRP on margins and profits appears to have been stronger for banks that: are small; have 'interest-oriented' business models; are real estate and mortgage specialists; are well capitalised; lend within national borders; weakly hedge against interest rate risk; operate in competitive banking systems; and where floating loan rates predominate. These empirical

results revealed from the paper calls for greater policy emphasis on the appropriate supervision and monitoring of banks profitability in countries that are more affected by the policy.

References

Albertazzi, U., Gambacorta, L., 2009. Bank profitability and the business cycle. *Journal of Financial Stability* 5, 393-409.

Alessandri, P., Nelson, B., 2015. Simple banking profitability and the yield curve. *Journal of Money, Credit and Banking* 47, 143-75.

Almarzoqi, R., Naceur, S. B., 2015. Determinants of bank interest margin in the Caucasus and Central Asia. *International Monetary Fund Working Paper* 15/87, April. Washington DC: IMF.

Altavilla, C., Boucinha M., Peydro, J. L., 2017. Monetary policy and bank profitability in a low interest rate enviroment. ECB Working Paper Series No 2105, October. Frankfurt: European Central Bank.

Angbazo, L., 1997. Commercial bank net interest margin, default risk, interest rate risk, and off-balance sheet banking. *Journal of Banking & Finance* 21, 57-87.

Arseneau, D. M., 2017. How would US banks fare in a negative interest rate environment? *Finance and Economics Discussion Series* 2017-030, March. Washington DC: Board of Governors of the Federal Reserve System, doi: https://doi.org/10.17016/FEDS.2017.030.

Arteta, C., Kose, M.A., Stocker, M., Taskin, T., 2016. Negative interest rate policies: Sources and implications. *World Bank Policy Research Paper 7791,* August. Washington DC: World Bank.

Athanasoglou, P. P., Brissimis, S. N., Delis, M. D., 2008. Bank-specific industry-specific and macroeconomic determinants of bank profitability. *Journal of International Financial Markets, Institutions and Money* 18, 121-136.

Bech, M., Malkhozov, A., 2015. How have central banks implemented negative policy rates? Bank for International Settlements, *(BIS) Quarterly Review*, March, 31-44. Basel: BIS.

Beck, T., Hess, H., 2009. Why are interest spreads so high in Uganda? *Journal of Development Economics* 88, 192-204.

Beck, T., Levine, R. Levkov, A., 2010. Big bad banks? The winner and the losers from the deregulation in the United States. *Journal of Finance* 65, 1367-1667.

Berger, A. N., 1995. The profit-structure relationship in banking: Test of market-power and efficient-structure hypotheses. *Journal of Money, Credit and Banking* 27, 404-431.

Berger, A. N., Kick, T., Schaeck, K., 2014. Executive board composition and bank risk taking. *Journal of Corporate Finance* 28, 48-65.

Bernanke, B., Reinhart, V., 2004. Conducting monetary policy at very low short-term interest rates. *American Economic Review* 94, 85–90.

Bernanke, B. 2016. What tools does the FED have left? Part 1: Negative interest rates. *Brookings Institution* (blog), March 18, Washington DC: Brookings Institution.

Bertrand, M., Mullainathan, S., 2003. Enjoying the quiet life? Corporate governance and managerial preferences, *Journal of Political Economy* 111, 1043-1075.

Bertrand, M., Duflo, E., Mullainathan, S., 2004. How much should we trust difference-in-differences estimates? *Quarterly Journal of Economics* 119, 249-275.

Blot, C., Huber, P. 2016. Negative interest rates: incentive or hindrance for the banking system? Monetary Dialogue European Parliament. Directorate General for Internal Policy. EC: Brussels.

Borio, C., Gambacorta, L., & Hofmann, B. (2015). The influence of monetary policy on bank profitability. *Bank for International Settlements Working Papers* No 514, October. Basel: BIS. https://doi.org/10.1111/infi.12104

Boyd, J., Levine, R., Smith, B., 2001. Inflation and financial market performance. *Journal of Monetary Economics* 47, 221-248.

Brunnermeier, M.K., Koby, Y., 2016. The reversal interest rate: the effective lower bound of monetary policy. Princeton University Department of Economics Working Paper August 27. Princeton NJ: Princeton University. https://scholar.princeton.edu/sites/default/files/markus/files/08f_reversalrate.pdf

Busch, R., Memmel, C., 2017. Banks' net interest margin and the level of interest rates. *Credit and Capital Markets* 50, *363–392*

Calderon, C., Schaeck, K., 2013. Bank bailouts, competition, and the disparate effects for borrowers and depositor welfare. *World Bank Policy Research Working Paper* 6410, April. Washington: World Bank.

Carbo', S., Fernandez, F. R. 2007. The determinants of bank margins in European banking. *Journal of Banking & Finance* 31, 2043-2063.

Chakraborty, I., Goldstein, I, MacKinlay, A., 2017. Monetary stimulus and bank lending. Finance Down Under 2017 Building on the Best from the Cellars of Finance. June. doi: http://dx.doi.org/10.2139/ssrn.2734910

Chaudron, R. F. D. D. 2018. Bank's interest rate risk and profitability in a prolonged environment of low interest rates. *Journal of Banking & Finance* 89, 94-104

Claessens, S., Coleman, N., Donnelly, M., 2018. Low-for-long interest rates and banks' interest margin and profitability: cross-country evidence. *Journal of Financial Intermediation* 35, 1-16.

Claessens, S., Laeven, L., 2003. What drives bank competition? Some international evidence. *Journal of Money, Credit and Banking* 36, 563-583.

Coeuré B. 2016. Assessing the implication of negative interest rate. Speech at the Yale Financial Crisis Forum in New Haven. July 28, 2016.
doi: https://www.ecb.europa.eu/press/key/date/2016/html/sp160728.en.html .

Covas, F, B., Rezende, M., Vojtech, C, M., 2015. Why are net interest margin of large banks so compressed? Board of Governors of the Federal Reserve System, *FEDS Notes*, October. Washington DC: Federal Reserve.
doi: https://www.federalreserve.gov/econresdata/notes/feds-notes/2015/why-are-net-interest-margins-of-large-banks-so-compressed-20151005.html.

Dell'Ariccia, G., Laeven, L., Marquez, R., 2010. Monetary policy, leverage and bank risk taking. *International Monetary Fund Working Paper* 10/276 December. Washington DC: IMF.

Demiralp, S., Eisenschmidt, J., and Vlassopoulos, T. (2017) Negative interest rates, excess liquidity and bank business models: Banks' reaction to unconventional monetary policy in the euro area. *KOÇ University-Tusiad Economic Research Forum Working Paper Series* No 1708. March. Istanbul: Koç University.

Demirgüç-Kunt, A., and Huizinga, H., 1999. Determinants of commercial bank interest margins and profitability: some international evidence, *World Bank Economic Review* 13, May, 379-408. Washington DC: World Bank.

Demirgüç-Kunt, A., Laeven, L., Levine, R., 2004. Regulations, market structure, institutions, and the cost of financial intermediation. *Journal of Money, Credit and Banking* 36, 593-622.

Di Maggio, M., Kermani, A., and Palmer, C., 2016, How quantitative easing works: Evidence on the refinancing channel. *National Bureau of Economic Research Working Paper* No. 22638, September, Washington D.C: NBER.

Donald, S., Lang, K., 2007. Inference with difference-in-differences and other panel data. *Review of Economics and Statistics* 89, 221-233.

Eggertsson, G, B., Juelsrud, R, E., Wold, E, G. 2017. Are negative nominal interest rate expansionary? *National Bureau of Economic Research Working Paper* No. 24039, March. Washington DC: NBER.

English, W, B., 2002. Interest rate risk and bank net interest margin. *Bank for International Settlements (BIS) Quarterly Review*, December, 67-92, Basel: BIS.

Entrop, O., Memmel, C., Ruprecht, B., Wilkens, M., 2015. Determinants of bank interest margin: impact of maturity transformation. *Journal of Banking & Finance* 54, 1-19.

Flannery, M, J., 1981. Market interest rate and commercial bank profitability: an empirical investigation. *Journal of Finance* 36, 1085-1101.

Fiordelisi, F., Ricci, O., Stentella Lopes, F. S., 2017. The unintended consequence of the Single-Supervisory Mechanism launch in Europe. *Journal of Financial and Quantitative Analysis* 52, 2809-2836.

Gambacorta, L., Hofmann, B. and Peersman, G., 2014. The effectiveness of unconventional monetary policy at the zero lower bound: A cross-country analysis. *Journal of Money, Credit and Banking* 46, 615–642.

Gelos, R., 2006. Banking Spreads in Latin America. *International Monetary Fund Working Paper 06/44*, February, Washington: IMF.

Genay, H., Podjasek, R., 2014. What is the impact of low interest rate environment on bank profitability? *Chicago Federal Reserve Letter* 324, July. Chicago: Chicago Fed.

Gertler, M., Kiyotaki, N., 2011. Financial intermediation and credit policy in business cycle analysis. In Friedman, B., and Woodford, M., (Eds.), *Handbook of Monetary Economics*. Elsevier, Amsterdam: Netherlands.

Goddard, J., Molyneux, P., Wilson, J. O. S., 2004. The profitability of European banks: A cross-sectional and dynamic panel analysis. *Manchester School* 72, 363-381.

Gross, D., 2016. Low rates = low bank profits? Monetary Dialogue. European Parliament. Directorate General for Internal Policy. Brussels: EC.

Hancock, D., 1985. Bank profitability, interest rates, and monetary policy. *Journal of Money, Credit and Banking* 17, 189-202.

Hanweck, G., Ryu, L., 2005. The sensitivity of bank net interest margin and profitability to credit, interest-rate, and term-structure shocks across bank product specialisation. *Federal Deposit Insurance Corporation (FDIC) Working Paper* No 2005-02, January. Washington DC: FDIC.

Hawtrey, K., Liang, H., 2008. Bank interest margins in OECD countries. *North American Journal of Economics and Finance* 19, 249-260.

Heckman, J., Ichimura, H., Smith, J.A., Todd, P., 1998. Characterizing selection bias using experimental data. *Econometrica* 65, 1017-1098.

Heider, F., Saidi, F., Schepens, G., 2017. Life below zero: bank lending under negative policy rates. Available at SSRN: https://ssrn.com/abstract=2788204

Ho, T S. Y., and Saunders, A., 1981. The determinants of bank interest margins:
Theory and empirical evidence, *Journal of Financial and Quantitative Analysis* 16, 581-600.

Imbens, G. W., Wooldridge, J. M., 2009. Recent developments in the econometrics of program evaluation. *Journal of Economic Literature* 47, 5-86.

IMF., 2017. Negative interest rate policies - Initial experiences and assessments. *IMF Policy Paper*. August. International Monetary Fund. Washington DC: IMF

Jayaratne, J., Strahan, P. E., 1996. The finance-growth nexus: Evidence from bank branch deregulation. *Quarterly Journal of Economics* 101, 639-670.

Jobst, A., Lin, H., 2016. Negative interest rate policy (NIRP): implications for monetary transmission and bank profitability in the euro area. *International Monetary Fund Working Paper 16/172,* August. Washington D.C: IMF.

Kandrac, J., and Schulsche, B., 2017. Quantitative easing and bank risk taking: evidence from lending. (September 25). Available from http://dx.doi.org/10.2139/ssrn.2684548

Lambert, F., Ueda, K., 2014. The effects of unconventional monetary policies on bank soundness. *International Monetary Fund Working Paper 14/152,* August, Washington DC: IMF.

Lechner, M., 2010. The estimation of causal effects by difference-in-difference methods. *Foundations and Trends in Econometrics* 4, 165-224.

Lepetit, L., Nys, E., Rous, P., Tarazi, A., 2008. The expansion of services in European banking: implications for loan pricing and interest margins. *Journal of Banking & Finance* 32, 2325-2335.

Lopez, J, A. Rose, K. A., Spiegel, M, M. 2018. Why have negative nominal interest rate had such a small effect on bank performance? Cross country evidence. *Federal Reserve Bank of San Francisco Working Paper* 2018-07, June. San Francisco: Federal Reserve Bank of San Francisco.

Maudos, J., Fernandez de Guevara, J., 2004. Factors explaining interest margin in the banking sectors of the European Union. *Journal of Banking & Finance* 28, 2259-2281.

Madous, J., Solis, L., 2009. The determinants of net interest income in the Mexican banking system: an integrated model. *Journal of Banking & Finance* 33, 1920-1931.

McAndrews, J., 2015. Negative nominal central bank policy rates: where is the lower bound? Remarks at the University of Wisconsin, May 8, New York Federal Reserve Speeches. https://www.newyorkfed.org/newsevents/speeches/2015/mca150508.html

McShane, R. W., Sharpe, I. G., 1985. A time series/cross section analysis of the determinants of Australian trading bank loan/deposit interest margin: 1962-1981. *Journal of Banking & Finance* 9, 115-136.

Mirzaei, A., Moore, T., Liu, G., 2013. Does market structure matter on bank's profitability and stability? Emerging vs. advanced economies. *Journal of Banking & Finance* 37, 2920-2937.

Molyneux, P., Thornton, J., 1992. Determinants of European banking profitability: A note. *Journal of Banking & Finance* 16, 1173-1178.

Petersen, M., 2009. Estimating standard error in finance panel dataset: comparing approaches. *Review of Financial Studies* 22, 435-480.

Poghosyan, T., 2013. Financial intermediation costs in low-income countries: the role of regulatory, institutional, and macroeconomic factors. *Economic Systems* 37, 92-110.

Riksbank., 2016. How do low and negative interest rate affect banks' profitability? *Monetary Policy Report* , April 2016, Stockholm: Sveriges Riksbank.

Roberts, M. R., Whited, T. M., 2012. Endogeneity in empirical corporate finance. *Handbook of the Economics of Finance*, Editors G.M. Constantinides, M. Harris and R. M. Stulz, Volume 2 Part A, Chapter 7, 493-572 (NY: Elsevier)

Rodnyansky, A., Darmouni, O., 2017. The effects of quantitative easing on bank lending behavior. *The Review of Financial Studies* 30, 3858-3887.

Rosenbaum, P. R., Rubin, D. B., 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika* 70, 41–55

Saunders, A., Schumacher, L., 2000. The determinants of bank interest rate margins: an international study. *Journal of International Money and Finance* 19, 813-832.

Shin, H. S. 2016. Bank capital and monetary transmission. *Panel Remarks at the ECB and its Watchers XVII Conference*, Frankfurt, April 7, 2016.

Sørensen, K. C., Werner, T., 2006. Bank interest rate pass-through in the euro area: a cross-country comparison. *European Central Bank Working Paper Series 580*, January. Frankfurt: ECB.

Witmer, J., Yang, J. (2016) Estimating Canada's effective lower bound, *Bank of Canada Review*, Spring, 3-14. Ottawa: Bank of Canada.

Table 1. Macroeconomic and institutional variables descriptive statistics divided by the treatment and control group (percentage values).

Country	NIRP adoption	Number of banks	GDP growth	Inflation	Unemployment	Yield curve	Credit-to-GDP	CB_GR	M0_GR	Lerner index	Loans rate	Deposits rate	Reserve	Taxation	Depth credit info	Legal rights
Treatment Group																
			0.21	2.04	4.73	1.65	128.63	0.05	5.95	0.23	3.64	1.27	2.80	4.87	5.50	4.00
Austria	Jun-14	357	(0.09)	(0.50)	(0.30)	(0.60)	(4.59)	(23.17)	(10.87)	(0.03)	(1.25)	(1.11)	(0.08)	(0.43)	(0.86)	(0.00)
			0.20	1.21	8.13	2.00	131.93	0.05	5.06	0.19	5.33	1.93	2.20	5.59	4.25	4.00
Belgium	Jun-14	72	(0.16)	(0.97)	(0.45)	(0.82)	(19.45)	(23.17)	(1.99)	(0.01)	(0.87)	(1.34)	(0.14)	(0.44)	(0.43)	(0.00)
			0.34	-0.50	4.36	0.55	175.96	14.05	23.57	0.12	3.18	0.08	4.16	4.90	5.25	6.00
Switzerland	Jan-15	422	(0.17)	(0.47)	(0.12)	(0.37)	(3.74)	(17.60)	(20.10)	(0.09)	(0.93)	(0.07)	(0.25)	(0.12)	(0.43)	(0.00)
			0.28	1.16	5.23	1.24	141.97	0.05	6.64	0.12	4.21	1.41	1.82	7.88	6.50	6.00
Germany	Jun-14	1914	(0.14)	(0.66)	(0.16)	(0.37)	(8.84)	(23.17)	(12.94)	(0.01)	(0.74)	(0.09)	(0.09)	(0.10)	(0.86)	(0.00)
	Jul-12															
	Apr-14		0.10	1.05	7.03	1.29	219.43	-8.52	3.05	0.31	5.33	1.37	4.66	4.23	4.50	8.00
Denmark	Sep-14	95	(0.15)	(0.80)	(0.36)	(0.38)	(6.54)	(14.17)	(1.16)	(0.02)	(1.40)	(1.05)	(0.43)	(0.20)	(0.86)	(0.00)
			0.56	1.46	8.80		73.61	0.05		0.18	4.21	1.24	7.12	2.07	5.50	7.00
Estonia	Jun-14	10	(0.39)	(1.86)	(1.00)		(2.60)	(23.17)		(0.00)	(1.27)	(1.22)	(0.24)	(1.43)	(0.87)	(0.00)
			0.13	0.80	25.4	3.72	218.56	0.05	-1.99	0.29	3.46	1.66	1.27	4.46	5.50	5.00
Spain	Jun-14	162	(0.63)	(1.19)	(0.66)	(1.58)	(18.85)	(23.17)	(5.81)	(0.02)	(0.92)	(1.14)	(0.18)	(0.49)	(0.86)	(0.00)
			-0.14	1.27	8.13	1.46	157.19	0.05	4.85	0.07	2.87	1.40	3.02	5.08	4.50	7.00
Finland	Jun-14	64	(0.31)	(1.08)	(0.41)	(0.43)	(9.35)	(23.17)	(1.68)	(0.00)	(0.07)	(1.25)	(0.29)	(0.41)	(0.86)	(0.00)
			0.18	0.84	10.06	1.96	146.59	0.05	2.76	0.19	3.78	2.81	1.98	8.07	4.50	4.00
France	Jun-14	410	(0.11)	(0.70)	(0.23)	(0.72)	(1.56)	(23.17)	(6.43)	(0.10)	(1.08)	(1.47)	(0.12)	(0.19)	(0.86)	(0.00)
			-0.39	-0.61	25.9	12.66	137.29	0.05	6.39	0.21	5.41	3.12	3.22	3.41	5.50	3.00
Greece	Jun-14	14	(0.50)	(1.26)	()1.27)	(6.87)	(1.41)	(23.17)	(2.66)	(0.01)	(0.78)	0.08)	(0.47)	(0.60)	(0.87)	(0.00)
			0.43	1.77	9.63	5.51	63.05	-6.46	8.99	0.13	5.46	2.72	4.53	3.86	4.25	8.66
Hungary	Mar-14	46	(0.60)	(2.37)	(1.33)	(1.63)	(3.85)	(11.87)	(5.02)	(0.00)	(1.16)	(1.22)	(0.58)	(0.35)	(0.43)	(1.89)
			2.43	0.52	13.13	3.51	166.18	0.05	5.53	0.28	3.55	2.84	2.78	5.04	5.50	7.00
Ireland	Jun-14	59	(2.68)	(0.73)	(1.26)	(2.13)	(37.69)	(23.17)	(14.13)	(0.00)	(1.07)	(1.47)	(0.23)	(1.15)	(0.86)	(0.00)
			-0.16	1.13	11.8	3.55	172.97	0.05	0.74	0.07	3.92	2.27	0.74	4.05	5.50	2.00
Italy	Jun-14	608	(0.34)	(1.19)	(0.78)	(1.36)	(2.79)	(23.17)	(5.12)	(0.01)	(1.26)	(1.02)	(0.03)	(0.68)	(0.86)	(0.00)
			0.93	1.37	5.70	1.34	194.19	0.05	8.68	0.31	3.40	1.58	3.47	6.45		3.00
Luxembourg	Jun-14	106	(0.69)	(0.88)	(0.43)	(0.59)	(6.25)	(23.17)	(5.91)	(0.01)	(1.25)	(1.40)	(0.57)	(0.16)		(0.00)
The			0.19	1.63	6.30	1.57	283.85	0.05	5.24	0.16	4.29	2.66	4.22	6.40	4.50	2.00
Netherlands	Jun-14	79	(0.29)	(0.85)	(0.71)	(0.47)	(4.52)	(23.17)	(1.82)	(0.01)	(1.33)	(1.38)	(0.04)	(0.23)	(0.86)	(0.00)
			0.39	1.75	3.36	2.23	132.93	10.00	-5.41	0.40	4.39	2.95	2.56	10.26	4.50	5.00
Norway	Sep-15	168	(0.21)	0.60)	(0.12)	(0.40)	(7.98)	(10.78)	(19.40)	(0.01)	(0.71)	(0.05)	(0.02)	(0.17)	(0.86)	(0.00)
			-0.41	0.81	15.43	5.70	182.54	0.05	4.68	0.28	4.51	2.61	1.37	5.80	5.50	2.00
Portugal	Jun-14	136	(0.64)	(1.16)	(0.94)	(3.26)	(13.39)	(23.17)	(1.49)	(0.01)	(1.27)	(0.07)	(0.07)	(0.29)	(0.86)	(0.00)

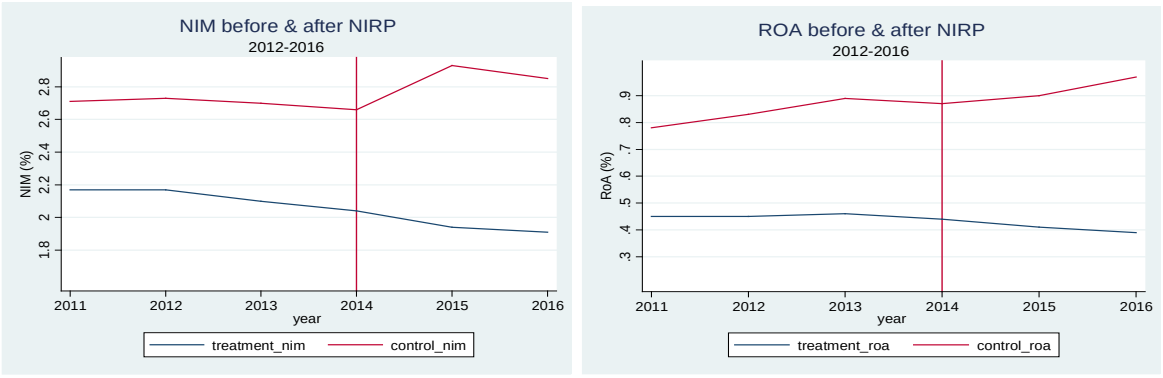
Sweden	Feb-15	111	0.65 (0.35)	0.15 (0.42)	8.06 (0.47)	1.53 (0.51)	153.33 (3.33)	11.05 (12.41)	-5.05 (2.06)	0.40 (0.01)	3.72 (1.11)	1.38 (1.14)	1.01 (0.04)	7.37 (0.36)	4.25 (0.43)	6.00 (0.00)
Slovenia	Jun-14	19	0.17 (0.59)	1.01 (1.23)	9.50 (0.57)	4.15 (1.75)	78.61 (9.84)	0.05 (23.17)	6.15 (3.16)	0.10 (0.02)	4.60 (1.09)	2.32 (1.04)	4.04 (0.51)	3.78 (1.34)	3.00 (0.71)	3.00 (0.00)
Slovakia	Jun-14	18	0.58 (0.29)	1.15 (1.57)	13.80 (0.37)	2.41 (1.10)	65.96 (4.62)	0.05 (23.17)	6.93 (5.88)	0.11 (0.01)	4.97 (0.08)	1.71 (0.09)	2.84 (0.46)	6.53 (0.74)	4.50 (0.87)	7.00 (0.00)
Total treatment		4870														
Mean treatment			0.34 (0.10)	0.96 (0.15)	10.58 (0.80)	3.10 (0.40)	152.20 (6.55)	0.57 (2.22)	5.45 (1.04)	0.20 (0.01)	4.20 (0.01)	2.04 (0.00)	3.01 (0.17)	5.26 (0.18)	4.65 (0.17)	4.98 (0.28)
Control Group																
Australia		145	0.62 (0.69)	2.05 (0.42)	5.63 (0.33)	3.51 (0.47)	162.15 (9.78)	9.96 (20.31)	-1.96 (7.00)	0.15 (0.02)	5.33 (0.79)	3.15 (0.04)	3.33 (0.06)	6.92 (0.13)	5.50 (0.86)	11.00 (0.00)
Canada		124	0.40 (0.29)	1.35 (0.40)	7.06 (0.12)	1.97 (0.30)	193.92 (8.57)	3.74 (14.63)	5.10 (0.74)	0.40 (0.02)	4.17 (0.08)	1.80 (0.09)	2.24 (0.10)	6.57 (0.23)	6.50 (0.86)	9.00 (0.00)
Chile		57	0.70 (0.32)	3.42 (1.00)	6.26 (0.18)	4.98 (0.39)	117.08 (3.43)	-4.41 (3.70)	8.73 (3.22)	0.31 (0.00)	6.39 (1.22)	3.22 (0.06)	5.02 (4.57)	3.99 (0.66)	5.00 (0.70)	4.00 (0.00)
Czech Republic		40	0.42 (0.50)	1.34 (1.20)	6.73 (0.37)	1.76 (0.80)	69.77 (1.64)	11.30 (10.93)	5.07 (1.76)	0.32 (0.00)	5.18 (1.42)	1.86 (1.06)	6.00 (1.21)	6.03 (0.18)	5.50 (0.86)	6.33 (0.94)
Great Britain		505	0.54 (0.20)	1.72 (1.10)	7.26 (0.71)	2.19 (0.29)	175.03 (12.02)	2.78 (13.54)	4.73 (0.63)	0.21 (0.00)	4.53 (1.22)	1.82 (1.11)	7.38 (0.24)	5.28 (0.60)	6.50 (0.86)	7.00 (0.00)
Iceland		36	0.74 (0.18)	0.77 (0.94)	6.43 (0.34)	6.40 (0.23)	128.95 (19.58)	3.71 (23.17)		0.21 (0.00)	4.23 (0.55)	1.26 (0.07)	13.28 (0.92)	7.97 (1.07)	5.50 (0.87)	5.00 (0.00)
Israel		16	0.71 (0.72)	3.18 (1.44)	5.53 (0.41)	3.28 (0.88)	84.35 (1.31)	-14.97 (20.96)	9.20 (2.87)	0.25 (0.01)	6.88 (0.52)	3.33 (0.01)	9.89 (0.35)	5.63 (0.59)	5.50 (0.86)	6.00 (0.00)
Korea		102	0.70 (0.12)	1.36 (0.53)	3.26 (0.17)	3.05 (0.44)	159.97 (4.35)	1.27 (4.92)	15.08 (2.23)	0.32 (0.00)	5.17 (1.38)	2.70 (0.09)	2.02 (0.28)	4.68 (0.25)	6.50 (0.86)	5.00 (0.00)
Mexico		186	0.58 (0.20)	3.66 (0.55)	4.85 (0.17)	5.80 (0.17)	49.54 (2.56)	8.05 (5.08)	11.67 (4.42)		6.68 (0.98)	3.25 (0.04)	4.64 (0.30)	5.76 (0.28)	6.50 (0.86)	8.33 (0.00)
New Zealand		36	0.63 (0.25)	0.93 (0.36)	6.23 (0.53)	3.87 (0.34)	176.10 (1.85)	-6.47 (11.48)	5.64 (1.60)	0.23 (0.00)	5.73 (1.07)	3.27 (0.03)	3.11 (0.49)	10.07 (0.44)	5.75 (1.30)	12.00 (0.00)
Poland		172	0.61 (0.43)	1.04 (1.72)	9.90 (0.51)	3.81 (0.83)	68.87 (3.50)	-0.81 (7.61)		0.34 (0.02)	5.40 (1.29)	2.72 (0.07)	2.82 (0.21)	4.40 (0.35)	6.50 (0.86)	7.00 (0.00)
Turkey		149	0.91 (0.36)	8.23 (1.31)	9.03 (0.23)		73.22 (3.87)	7.40 (11.12)	4.67 (10.26)	0.42 (0.01)	6.66 (1.02)	3.26 (0.05)	4.46 (0.08)	5.40 (0.06)	5.50 (0.86)	2.00 (0.00)
USA		921	0.51 (0.13)	1.31 (0.72)	7.26 (0.82)	2.20 (0.27)	241.88 (7.28)	14.41 (16.36)	10.46 (8.82)	0.33 (0.00)	5.40 (0.09)	1.25 (1.57)	3.95 (0.13)	8.14 (0.67)	7.00 (1.00)	11.00 (0.00)
Total control		2489														
Mean control			0.60 (0.04)	2.30 (0.28)	6.30 (0.28)	3.47 (0.21)	130.98 (7.46)	3.07 (1.80)	6.08 (1.22)	0.30 (0.01)	5.55 (0.01)	2.57 (0.01)	5.05 (0.42)	6.51 (0.26)	5.87 (0.15)	7.04 (0.44)
T-test			0.26**	1.33***	-4.27***	0.36	-21.21**	2.49	0.62	0.10***	1.31***	0.05***	2.03***	1.25***	1.21***	2.06***

NIRP-affected floating rate countries: Germany, Austria, Spain, Finland, Greece, Ireland, Italy, Luxembourg, Portugal, Sweden and Slovenia.

NIRP-affected fixed rate countries: Denmark, France, Hungary, Norway, the Netherlands and Slovakia,

Note: The Table displays mean and standard deviation (in parentheses) for the sample of countries divided by the treatment (Treatment group) and control group (Control group). NIRP adoption displays the time of adoption of NIRP. Number of banks is the number of banks used in the sample by country. GDP growth is the yearly growth rate of real GDP. Inflation is the yearly Consumer Price Index in percentage. Unemployment is the yearly level of unemployment in percentage. Yield curve is the 10-year government bond return. Credit-to-GDP is the ratio of aggregate gross loans to real GDP. CB_GR is the logarithmic yearly growth rate of central bank total assets. M0_GR is the logarithmic yearly growth rate of the money supply M0. Lerner index is the Lerner index. Loans rate is the ratio of interest on loans to total gross loans. Deposits rate is the ratio of interest expenses to total deposits. Reserve is the ratio of cash and balances at the central bank on total assets. Taxation is the ratio of taxes on operating income. Depth credit info is the depth of credit information index. Legal rights is the legal rights index. Floating-Fixed Rate is the share of variable loans in total loans to household and non-financial corporation. Floating rate countries are those that have a share of variable rate loans to total loans greater than 63% (median), and vice versa for fixed-rate countries. T-test difference in means between Mean treatment and Mean control is also reported in the Table. ***, **, * indicate statistical significance at 1%, 5% and 10% respectively.

Figure 1. Average NIM and ROA among treated banks (blue line) and non-treated banks (red line) from 2011 – 2016. Correlation of NIM and ROA among the treatment and control group prior to NIRP-introduction is 0.94 for NIM and 0.58 for ROA, respectively. Correlation of NIM and ROA among the treatment and control group after NIRP-introduction is -0.87 for NIM and -0.94 for ROA, respectively.



Note: NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income to total assets ratio.

Table 2. Descriptive statistics of control and treatment group prior to and after the introduction of NIRP.

TREATMENT

	Pre-NIRP					NIRP Period				
Variables	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Panel A: Bank Profitability and Margins										
NIM	8916	2.06%***	0.95%	0.49%	4.12%	8040	1.92%***	0.78%	0.49%	4.12%
ROA	9025	0.47%***	0.59%	0.00%	2.29%	8108	0.40%***	0.97%	0.00%	2.29%
Panel B: Bank Balance Sheet										
Size	9048	13.79***	1.59	11.51	16.58	8138	13.76***	1.58	11.51	16.58
Lending diversification	250	0.81%	0.20%	0.02%	0.69%	330	0.80%	0.20%	0.01%	0.69%
E/TA	9046	10.06%***	5.28%	4.07%	21.76%	8136	10.22%***	5.01%	4.07%	21.76%
Tier1 ratio	5158	14.70%***	4.46%	9.88	23.99	5306	16.16%***	4.54%	10.70	25.00
Liquidity	8549	21.00%***	14.00%	1.00%	46.00%	7895	21.73%	15.09%	0.07%	46.68%
Credit risk	8111	0.29%***	0.41%	0.00%	1.17%	7401	0.25%	0.42%	0.00%	1.17%
Cost-to-income	5042	71.35%***	15.11%	47.09%	95.28%	7664	72.70%***	15.00%	47.09%	95.28%
Loan growth	8131	3.58%***	6.66%	-7.27%	15.36%	7630	3.32%***	6.45%	-7.27%	15.36%
Off-balance sheet	4505	7.88%***	6.16%	1.65%	21.46%	6549	7.67%***	6.12%	1.65%	21.46%
Non-interest income	8842	35.72%***	23.45%	12.50%	87.67%	8019	37.48%	22.90%	12.50%	87.67%
Fees & Commissions	8662	0.77%***	0.60%	0.00%	2.16%	7855	0.80%***	0.59%	0.00%	2.16%
Interest income	4658	3.02%***	1.13%	1.06%	3.67%	7145	2.55%***	0.79%	1.06%	3.67%
Interest expenses	4609	1.17%***	0.64%	0.25%	1.65%	7066	0.82%***	0.43%	0.25%	1.65%

CONTROL

	Pre-NIRP					NIRP Period				
Variables	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Panel C: Bank Profitability and Margin										
NIM	4686	2.92%***	1.71%	0.39%	6.15%	4331	2.93%***	1.65%	0.39%	6.15%
ROA	4811	1.03%***	1.00%	-0.10%	3.26%	4457	1.03%***	0.97%	-0.10%	3.26%
Panel D: Bank Balance Sheet										
Size	5008	14.33***	1.98	11.21	17.63	4650	14.36***	2.07	11.21	17.63
E/TA	5006	16.46%***	13.93%	5.47%	51.27%	4648	16.66%***	13.89%	5.47%	51.27%

Tier1 ratio	2287	15.62%***	4.28	9.88	23.99	2101	15.63%***	4.45%	9.88	23.99
Liquidity	4374	22.00%***	19.00%	1.00%	64.00%	4341	22.04%	20.13%	0.09%	64.85%
Credit risk	3760	0.33%***	0.39%	0.00%	1.21%	3504	0.26%	0.38%	0.00%	1.21%
Cost-to-income	3319	63.87%***	16.08%	37.68%	90.89%	4135	65.46%***	16.60%	37.68%	90.89%
Loan growth	3735	6.35%***	12.92%	-11.50%	31.12%	3759	8.63%***	11.99%	-11.5%	31.12%
Off-balance sheet	2040	21.98%***	22.17%	0.70%	72.46%	2472	22.16%***	22.55%	0.71%	72.46%
Non-interest income	4534	38.10%***	29.94%	5.02%	96.61%	4349	37.33%	29.63%	5.02%	96.61%
Fees & Commissions	4236	0.58%***	0.68%	0.00%	2.10%	3948	0.59%***	0.67%	0.00%	2.10%
Interest income	2456	3.45%***	1.52%	0.83%	5.79%	3137	3.25%***	1.62%	0.83%	5.79%
Interest expenses	2380	1.27%***	0.97%	0.20%	2.81%	3034	1.19%***	0.96%	0.20%	2.81%

Note: NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income to total assets ratio. Size is the natural logarithm of bank total assets. Lending diversification is the ratio of loans inside the Euro area on total loans taken for a sample of SSM supervised banks (treatment group). E/TA is the ratio of bank equity to total assets. Tier 1 ratio is the Tier1 ratio as reported for regulatory purposes. Liquidity is the ratio of bank liquid securities to total assets. Credit risk is the ratio of loan loss provision to total assets. Cost-to-income is the ratio of operating expenses to operating income. Loan growth is the logarithm growth rate of gross loans. Off-balance sheet is the ratio of off-balance sheet items to total assets. Non-interest income is the ratio of non-interest income to gross revenues. Fees & commissions is the ratio of net fees and commissions to total assets. Interest income is the ratio of interest income to total assets. Interest expenses is the ratio of interest expenses on total assets. T-test difference in means between Mean treatment and Mean control prior and after NIRP is also reported. ***, **, * indicate statistical significance at 1%, 5% and 10% respectively.

Table 3. The effect of NIRP on NIM and ROA.

	NIM	ROA
NIRP-Effect	-0.1641***	-0.0306**
	(0.0183)	(0.0139)
Size	-0.1239***	0.0038
	(0.0080)	(0.0036)
E/TA	0.0234***	0.0322***
	(0.0026)	(0.0018)
Liquidity	-0.5165***	-0.1135***
	(0.0708)	(0.0411)
Loan growth	0.0031***	0.0030***
	(0.0006)	(0.0005)
Cost-to-income	-0.0041***	-0.0140***
	(0.0006)	(0.0005)
Credit risk	24.5769***	-27.2195***
	(2.1916)	(1.6302)
GDP growth	-0.0229	0.0292*
	(0.0190)	(0.0150)
Inflation	0.0610***	0.0242***
	(0.0066)	(0.0049)
Depth credit info	-0.0379***	-0.0048
	(0.0079)	(0.0083)
Legal rights	0.1904***	0.0670**
	(0.0450)	(0.0323)
Credit-to-GDP	-0.0039***	0.0005
	(0.0005)	(0.0004)
Yield curve	0.0199***	-0.0053
	(0.0059)	(0.0046)
Taxation	1.5347***	0.4216**
	(0.1688)	(0.1675)
Reserves	0.2768	0.7155***
	(0.2669)	(0.1947)
Observations	17,271	17,286
R-squared	0.513	0.566
Number of banks	4,612	4,612

Note: NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income to total assets ratio. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after NIRP implementation, 0 otherwise. Size is the natural logarithm of bank total assets. E/TA is the ratio of bank equity to total assets. Liquidity is the ratio of bank liquid securities to total assets. Cost-to-income is the ratio of operating expenses to operating income. Credit risk is the ratio of loan loss reserves to total assets. Loan growth is the logarithm growth rate of gross loans. GDP growth is the yearly growth rate of real GDP. Inflation is the yearly Consumer Price Index in percentage. Depth credit info is the depth of credit information index. Legal rights is the legal rights index. Credit-to-GDP is the ratio of aggregate gross loans to real GDP. Yield curve is the 10-year government bond return. Taxation is the ratio of taxes on operating income. Reserve is the ratio of cash and balances at the central bank on total assets. All regressions include fixed country and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 4. Propensity score estimation: Probit model

	NIM	**ROA**
GDP growth	-4.6537***	-4.6595***
	(0.0870)	(0.0870)
Inflation	-1.1712***	-1.1742***
	(0.0279)	(0.0279)
Size	-0.1934***	-0.1924***
	(0.0107)	(0.0106)
E/TA	-0.0468***	-0.0465***
	(0.0033)	(0.0033)
Loan growth	-0.0097***	-0.0098***
	(0.0019)	(0.0018)
Observations	11677	11730
Pseudo R square	0.5460	0.5468
Log Likelihood	-3291.54	-3300.36
LR test (chi square)	7918.52	7964.23

Note: NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income to total assets ratio. GDP growth is the yearly growth rate of real GDP. Inflation is the yearly Consumer Price Index in percentage**.** Size is the natural logarithm of bank total assets. E/TA is the ratio of bank equity to total assets. Loan growth is the logarithm growth rate of gross loans. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 5. Difference-in-differences - PSM results

	NIM	**ROA**
NIRP-effect	-0.1220***	-0.1010***
	(0.0180)	(0.0140)
Country FE	Y	Y
Year FE	Y	Y
Observations	22331	22520

Note: NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income to total assets ratio. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after

NIRP implementation, 0 otherwise. All regressions include fixed country and time effects. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 6. The influence of NIRP on NIM and ROA by splitting the sample in four percentiles based on bank size.

	Bank Size>75th percentile		Bank Size>50th & <75th percentile		Bank Size>25th & <50th percentile		Bank Size<25th percentile	
	NIM(1)	ROA(2)	NIM(3)	ROA(4)	NIM(5)	ROA(6)	NIM(7)	ROA(8)
Panel A.								
NIRP-effect	-0.0032		-0.1321***		-0.1695***		-0.1783***	
	(0.0203)		(0.0239)		(0.0281)		(0.0466)	
Panel B.								
NIRP-effect		0.0358**		-0.0670***		-0.0695***		-0.1409***
		(0.0183)		(0.0214)		(0.0254)		(0.0320)
R2	0.3552	0.2780	0.3102	0.2942	0.3711	0.2562	0.2956	0.1532
N.banks	1843	1855	2084	2115	2177	2195	2074	2159
N.Obs	6468	6514	6563	6637	6581	6629	6361	6621
T-test Bank size>25th & <50th = Bank size <25th						1.93***		
T-test Bank size >25th & <50th = Bank size>50th & <75th					1.27***			
T-test Bank size >75th = Bank size>50th & <75th			0.69***					

Note: Panel A displays difference-in-differences regression results of NIRP on NIM split by bank size percentiles. Panel B shows difference-in-differences regression results of NIRP on ROA split by bank size percentiles. NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income to total assets ratio. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after NIRP implementation, 0 otherwise. Size is the natural logarithm of bank total assets. We define banks in the first percentile as having an asset size smaller than $300 million. Banks in the second percentile with an asset size between $300 million and $1 billion. Banks in the third percentile an asset size between $1 and $4 billion. Banks in the last percentile with an asset size larger than $4 billion. All the percentile regressions include fixed country and time effects. T-test for difference in means among percentiles is reported. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 7. The influence of NIRP on non-interest income and fees and commissions by splitting the sample in four percentiles based on bank size.

	Bank Size>75th percentile		Bank Size>50th & <75th percentile		Bank Size>25th & <50th percentile		Bank Size<25th percentile	
	NII(1)	FEE(2)	NII(3)	FEE(4)	NII(5)	FEE(6)	NII(7)	FEE(8)
Panel A.								
NIRP-effect	2.5876***		3.476***		3.0223***		0.770	
	(0.443)		(0.489)		(0.602)		(0.835)	
Panel B								
NIRP-effect		0.0004***		0.0003***		0.0002		-0.00004
		(0.0001)		(0.0001)		(0.0001)		(0.0001)
R2	0.0999	0.1090	0.1340	0.1000	0.1562	0.1440	0.1528	0.0947
N.banks	1950	1765	2079	1970	2165	2076	2091	1945
N.Obs	6499	6197	6476	6234	6493	6309	6276	5961
T-test Bank size>25th & <50th = Bank size <25th						1.93***		
T-test Bank size >25th & <50th = Bank size>50th & <75th					1.27***			
T-test Bank size >75th = Bank size>50th & <75th			0.69***					

Note: Panel A displays difference-in-differences regression results of NIRP on NII split by bank size percentiles. Panel B shows difference-in-differences regression results of NIRP on FEE split by bank size percentiles Non-interest income (NII) is the ratio of non-interest income on gross revenues. Fees & commissions (FEE) is the ratio of fees and commissions income to total assets. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after NIRP implementation, 0 otherwise. Size is the natural logarithm of bank total assets. We define banks in the first percentile as having an asset size smaller than $300 million. Banks in the second percentile with an asset size between $300 million and $1 billion. Banks in the third percentile an asset size between $1 and $4 billion. Banks in the last percentile with an asset size larger than $4 billion. All the percentile regressions include fixed country and time effects. T-test for difference in means among percentiles is reported. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 8. The effect of NIRP on banks that: strongly (weakly) hedge against interest rate risk; have diversified lending; operate in more (less) competitive markets; in countries where floating (fixed) rates predominate; and for levels of bank capital.

	NIM(1)	ROA(2)	NIM(3)	ROA(4)	T-test
Panel A.					
Weak-hedging			**Strong hedging**		65.94%***
NIRP-Effect	-0.2048***	-0.0623**	-0.0887***	0.0164	
	(0.0299)	(0.0243)	(0.0211)	(0.0171)	
R-squared	0.295	0.246	0.352	0.291	
N.Banks	3,152	3,168	2,793	2,806	
N.Obs	10,394	10,448	8,914	8,951	
Panel B.					
Lending Diversification					
NIRP-Effect	0.0768	-0.0292			
	-0.0614	-0.0309			
R2	0.0107	0.0309			
N.Banks	224	225			
N.Obs	896	900			
Panel C.					
More Competitive			**Less Competitive**		0.20***
NIRP-effect	-0.0903**	-0.0632***	-0.0301	0.0851***	
	(0.0372)	(0.0247)	(0.0205)	(0.0193)	
R2	0.1643	0.0247	0.2788	0.1632	
N.Banks	4559	4640	3361	3443	
N.Obs	15096	15259	10877	11142	
Panel D.					
Fixed rate countries			**Floating rate countries**		26.20%***
NIRP-effect	0.0222	0.0286*	-0.0368**	0.0031	
	(0.0155)	(0.0141)	(0.0141)	(0.0107)	
R2	0.0058	0.0017	0.0244	0.0008	
N.Banks	3689	3773	6436	6543	
N.Obs	13095	13411	23066	23454	
Panel E.					
Less Capitalised			**More Capitalised**		6.40%***
NIRP-Effect	-0.0267	-0.0102	-0.1502***	-0.0937***	
	(0.0186)	(0.0151)	(0.0191)	(0.0154)	
R2	0.43	0.348	0.272	0.191	
N.Banks	2726	2726	6036	6153	
N.Obs	7428	7428	18545	18973	

Note: Panel A displays difference-in-differences regression results obtained by splitting the sample according to the median level of Off-balance sheet items on total assets. Weak-hedging is defined as those banks with less than 6% off-balance sheet assets to total assets ratio, and vice versa for Strong-hedging banks. Panel B presents difference-in-differences regression results for a sample of significantly supervised entities (SIs) belonging to the treatment group. The control group used has been created by applying nearest neighbour propensity score matching. Panel C displays difference-in-differences regression results obtained by splitting the sample between more competitive and less competitive banking sectors as measured by the Lerner index. More competitive systems are those banking sectors with a Lerner index below 0.24, and vice versa for less competitive markets. Panel D shows difference-in-differences results obtained by splitting the sample dividing the treatment group into floating and fixed rate countries. Fixed rate are those countries having a share of variable loans to total loans lower than 63% and vice versa for fixed-rate loans. Panel E presents difference-in-differences regression results obtained by splitting the sample between less and well capitalised banks. Banks are considered as less capitalised if they have Tier 1 ratio below the median value (14.37%) and vice versa for well capitalised banks. NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets.

ROA is the yearly net income to total assets ratio. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after NIRP implementation, 0 otherwise. Weak-hedging is the below median off-balance sheet to total assets ratio. Strong-hedging is the above median off-balance sheet to total assets ratio. Lending diversification is the ratio of loans inside the Europe on total loans. More competitive is the below median of the Lerner index. Less competitive is the above median level of Lerner index. Floating rate countries is the above median share of variable rate loans in total loans to households and non-financial corporations. Fixed rate countries is the below median share of variable rate loans in total loans to households and non-financial corporations. Less capitalised is the below median of tier1 ratio. More capitalised is the above median of tier1 ratio. T-test for difference in means among the median level of the variables is also reported. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 9. NIRP and bank specialisation.

	Bank Holdings Companies		Commercial Banks		Cooperative Banks		Finance Companies		Real Estate and Mortgage Banks		Savings Banks	
	NIM(1)	ROA(2)	NIM(3)	ROA(4)	NIM(5)	ROA(6)	NIM(7)	ROA(8)	NIM(9)	ROA(10)	NIM(11)	ROA(12)
Panel A.												
NIRP-effect	-0.0876		-0.1329***		-0.0793***		-0.2630***		-0.3012***		-0.0986***	
	(0.0680)		(0.0321		(0.0229)		(0.0742)		(0.0635)		(0.0282)	
Panel B.												
NIRP-effect		0.0232		-0.0504**		-0.0122		-0.1841***		-0.1274***		-0.0078
		(0.0466)		(0.0247)		(0.0296)		(0.0568)		(0.0494)		(0.0256)
R2	0.3921	0.1545	0.387	0.1741	0.3302	0.2517	0.2939	0.2302	0.3541	0.2491	0.6477	0.5123
N.Banks	527	531	1425	1446	1663	1664	581	603	226	226	1299	1299
N.Obs	1960	1980	5222	5287	6157	6162	1949	2026	857	859	4940	4940

Note: NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income to total assets ratio. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after NIRP implementation, 0 otherwise. Classification for bank holding companies, commercial banks, cooperative banks, finance companies, real estate and mortgage banks and saving banks it taken from Orbis Bank Focus. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 10. Robustness checks

Panel A. Lending rate, deposit rate, interest income and interest expense				
	NIM(1)	ROA(2)	Interest Income(3)	Interest Expense(4)
NIRP-effect	-0.1193***	-0.008	-0.0026***	-0.0016***
	(0.6900)	(0.0126)	(0.0001)	(0.0001)
Loans rate	7.0750***	3.0984***		
	(0.8746)	(0.3707)		
Deposits rate	-7.3207***	-2.8912***		
	(0.9049)	(0.5787)		
R2	0.4084	0.2929	0.3328	0.4203
N.Banks	5092	5098	5888	5776
N.Obs	15209	15223	17396	17091
Panel B. Unconventional Monetary Policy (UMP)				
	NIM(1)	ROA(2)	NIM(3)	ROA(4)
NIRP-effect	-0.1520***	-0.0584***	-0.1620***	-0.0842***
	(0.0144)	(0.0108)	(0.0142)	(0.0105)
CB_GR	-0.0393*	0.0733***		
	-0.0209	-0.0196		
M0_GR			-0.0012***	0.0005*
			-0.0003	-0.0003
R2	0.295	0.2124	0.2791	0.2004
N.Banks	7238	7354	5335	5422
N.Obs	25212	25627	19486	19809
	Panel C. NIRP and the EU		**Panel D. NIRP, no Switzerland, Norway and Sweden**	
	NIM(1)	ROA(2)	NIM(3)	ROA(4)
NIRP-effect	-0.1601***	-0.0584***	-0.1284***	-0.0589***
	(0.0286)	(0.0198)	(0.0154)	(0.0124)
R2	0.2189	0.128	0.261	0.212
N.Banks	5527	5623	6543	6658
N.Obs	19897	20244	23363	23784
	Panel E. Fake NIRP		**Panel F. NIRP at aggregate level**	
	NIM(1)	ROA(2)	NIM(3)	ROA(4)
NIRP-effect	-0.017	-0.0079	-0.0014	0.0033
	(0.0176)	(0.0169)	(0.0064)	(0.0153)
R2	0.124	0.0789	0.735	0.273
N.Banks/Countries	7183	7307	33	33
N.Obs	20123	20472	132	132

Note: Panel A (Columns 1 and 2) displays difference-in-differences regression results when both Loans rate and Deposits rate have been controlled for, while Columns 3 and 4 present results where the dependent variables are interest income (Column 3) and interest expenses (Column 4). Panel B shows the difference-in-differences regression results when proxies of unconventional monetary policies are included. Panel C reports difference-in-differences regression results when the treatment group includes only European NIRP adopters and the control group includes only European non-NIRP adopters. Panel D displays difference-in-differences regression results when late NIRP adopter countries (Switzerland, Norway and Sweden) have been removed from the sample. Panel E shows difference-in-differences regression results where the NIRP intervention has been set in 2013. Panel F displays difference-in-differences regressions results of the NIRP effect at the aggregate country level. NIM is the yearly difference between interest earning assets and interest bearing liabilities divided by total interest earning assets. ROA is the yearly net income to total assets ratio. NIRP-effect is the interaction between the dummy Treated and the dummy Post. It takes the value 1 if bank *i* in country *j* has been affected by NIRP after NIRP

implementation, 0 otherwise. Interest income is the ratio of interest income to total assets. Interest expenses is the ratio of interest expenses on total assets. Loans rate is the ratio of interest on loans to total gross loans. Deposits rate is the ratio of interest expenses to total deposits. . M0_GR is the logarithmic yearly growth rate of the money supply M0. CB_GR is the logarithmic yearly growth rate of central bank total assets.

Appendix

Table A1 Correlation Matrix. This table represents the correlation matrix among the variables used in the baseline regression. Correlations that are significant at least at 5% level are reported using bold italics. The number on the horizontal axis indicates the variables in the vertical axis. Each horizontal number matches with the variable's position in the vertical.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Size		**-0.27**	**0.07**	0.01	**-0.26**	**0.03**	**0.05**	**-0.03**	0.00	**0.15**	**0.22**	-0.00	**0.12**	**0.09**
E/TA	**-0.27**		**0.11**	**0.11**	**-0.08**	-0.01	**0.13**	**0.23**	**0.06**	**0.09**	**-0.2**	**0.12**	**-0.07**	**0.21**
Liquidity	**0.07**	**0.11**		**-0.06**	**0.06**	**-0.04**	**-0.02**	**0.03**	**0.13**	**0.07**	**0.06**	0.00	**0.02**	**-0.03**
Credit risk	0.01	**0.11**	**-0.06**		**-0.27**	**-0.06**	**-0.14**	**0.15**	**-0.12**	**-0.25**	**-0.04**	**0.33**	**-0.32**	0.00
Cost-to-income	**-0.26**	**-0.08**	**0.06**	**-0.27**		**-0.07**	**-0.03**	**-0.05**	**0.10**	**-0.02**	**-0.12**	**-0.13**	**-0.37**	**0.02**
Loan growth	**0.03**	-0.01	**-0.04**	**-0.06**	**-0.07**		**0.07**	**0.15**	**0.07**	**0.09**	**-0.07**	0.01	**0.08**	**0.05**
GDP growth	**0.05**	**0.13**	**-0.02**	**-0.14**	**-0.03**	**0.07**		**-0.07**	**0.18**	**0.31**	**0.10**	**-0.16**	**0.05**	**0.15**
Inflation	**-0.03**	**0.23**	**0.03**	**0.15**	**-0.05**	**0.15**	**-0.07**		**-0.26**	**-0.06**	**-0.16**	**0.37**	**-0.02**	**0.09**
Depth credit info	0.00	**0.06**	**0.13**	**-0.12**	**0.10**	**0.07**	**0.18**	**-0.26**		**0.52**	**0.36**	**-0.08**	**0.07**	**0.03**
Legal rights	**0.15**	**0.09**	**0.07**	**-0.25**	**-0.02**	**0.09**	**0.31**	**-0.06**	**0.52**		**0.73**	**-0.05**	**0.16**	**0.19**
Credit-to-GDP	**0.22**	**-0.20**	**0.06**	**-0.04**	**-0.12**	**-0.07**	**0.10**	**-0.16**	**0.36**	**0.73**		**-0.07**	**0.04**	**0.04**
Yield curve	-0.00	**0.12**	0.00	**0.33**	**-0.13**	0.01	**-0.16**	**0.37**	**-0.08**	**-0.05**	**-0.07**		**-0.10**	0.00
Taxation	**0.12**	**-0.07**	**0.02**	**-0.32**	**-0.37**	**0.08**	**0.05**	**-0.02**	**0.07**	**0.16**	**0.04**	**0.10**		**-0.09**
Reserve	**0.09**	**0.21**	**-0.03**	0.00	**0.02**	**0.05**	**0.15**	**0.09**	**0.03**	**0.19**	**0.04**	0.00	**-0.09**	

Note: Size is the natural logarithm of bank total assets. E/TA is the ratio of bank equity to total assets. Liquidity is the ratio of bank liquid securities to total assets. Credit risk is the ratio of loan loss reserves to total assets. Cost-to-income is the ratio of operating expenses to operating income. Loan growth is the logarithm growth rate of gross loans. GDP growth is the yearly growth rate of real GDP. Inflation is the yearly Consumer Price Index in percentage. Depth credit info is the depth of credit information index. Legal rights is the legal rights index. Credit-to-GDP is the ratio of aggregate gross loans to real GDP. Yield curve is the 10-year government bond return. Taxation is the ratio of taxes on operating income. Reserve is the ratio of cash and balances at the central bank on total assets.

Table A2. This table shows macroeconomic indicators and Pearson correlation test for the control and treatment group during the period 2007-2015. We arbitrarily chose a longer time period (in comparison with the sample period) to highlight that these macroeconomic indicators move together for several years after the GFC. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively.

Variable	Mean Control	Mean Treatment	Std.Dev. Control	Std.Dev. Treatment	Pearson Corr.
Unemployment	7.38	7.54	1.86	3.70	0.6978*
GDP growth	0.35	0.19	0.47	0.64	0.9021***
Inflation	2.04	1.47	1.53	1.22	0.8659***

Note: Unemployment is the yearly level of unemployment in percentage. GDP growth is the yearly growth rate of real GDP. Inflation is the yearly Consumer Price Index in percentage.

Table A3. This table displays variables, units, description and source of the variables used in the sample.

Variable	Units	Description	Source	Expected Sign NIM	Expected Sign ROA
Bank Profitability and Margin					
NIM	ratio	Net interest margin computed as the difference between interest earning assets and interest bearing liabilities divided by the amount of interest earning assets.	Orbis Bank Focus	n.a	n.a
ROA	ratio	Return on assets is calculated by dividing bank's net income by total assets.	Orbis Bank Focus	n.a	n.a
Dummy					
Treated	dummy	Treated is a dummy variable that takes the value 1 if bank i in country j has been affected by NIRP and 0 otherwise.		-	-
Post	dummy	Post is a dummy variable that takes the value 1 after a period that country j at time t decided to implement NIRP and 0 before that period.		-	-
Treatment	dummy	Treatment is the interaction between the dummy treated and the dummy post		-	-
Bank balance sheet					
Size	logarithm	Size is the natural logarithm of bank total assets.	Orbis Bank Focus	-	+
E/TA	ratio	E/TA is calculated as the ratio of bank equity on total assets.	Orbis Bank Focus	+	-/+
Liquidity	ratio	Liquidity is computed as the ratio of bank liquid securities on total assets.	Orbis Bank Focus	+	-/+
Credit risk	ratio	Credit risk is computed as the ratio of loan loss provisions on total assets.	Orbis Bank Focus & SNL financial	+	-/+
Cost-to-income	ratio	Cost-to-income ratio is calculated as the ratio of operating expenses on net operating income.	Orbis Bank Focus & SNL financial	-	-
Loan growth	percentage	Loan growth is the logarithmic growth rate of gross loans.	Orbis Bank Focus & SNL financial	+	+
Off-balance sheet	ratio	Off-balance sheet is computed as the ratio of off-balance sheet on total assets	Orbis Bank Focus	+	+
Non-interest income	ratio	Non-interest income is calculated as the ratio of non-interest income on gross revenues	Orbis Bank Focus	-	+
Fees & commissions	ratio	Fees & commissions is calculated as the ratio of fees and commissions income to total assets	Orbis Bank Focus	-	+
Interest income	ratio	Interest income is calculated as the ratio of interest income on total assets	Orbis Bank Focus	+	+
Interest expenses	ratio	Interest expenses is calculated as the ratio of interest expenses on total assets	Orbis Bank Focus	-	-

Macroeconomic Conditions and Monetary Policy					
GDP growth	percentage	GDP growth is calculated the yearly growth rate of real GDP.	Thompson Datastream	-/+	-/+
Inflation	percentage	Inflation is the yearly Consumer Price Index.	Thompson Datastream	+	+
Unemployment	percentage	Unemployment is the yearly level of unemployment.	World Bank Database	-	-
Yield curve	percentage points	Yield curve is measured as the 10-year government bond return.	Thompson Datastream	+	+
Credit-to-GDP	ratio	Credit-to-GDP is measured as the ratio of gross loans to real GDP.	Bank for International Settlement Database	+	+
CB_GR	percentage	CB_GR is the logarithm growth rate of central bank balance sheet size.	Orbis Bank Focus	-	+
M0_GR	percentage	M0_GR is the logarithm growth rate of of the money supply M0.	Thompson Datastream	-	+
Loans rate	ratio	Loans rate is the ratio of interest on loans to total gross loans.	Orbis Bank Focus	+	+
Deposits rate	ratio	Deposits rate is the ratio of interest expenses to total cost of deposits.	Orbis Bank Focus	-	-
Lerner index	positive number	The Lerner index is the difference between the price and the total marginal cost as a proportion of the price of banking services. It ranges between 0 (perfect competition) and 1 (monopoly).	World Bank Global Financial Development Database	-	-
Floating-fixed rate countries	ratio	Floating-fixed rate countries is computed as the share of variable rate loans in total loans to households and non-financial corporations.	European Central Bank Statistical Warehouse Database	-	-
Institutional Variables					
Depth of credit info	positive number	Depth of credit information index measures rules affecting the scope, accessibility, and high quality of credit information available through public or private credit register. The index ranges from 0 to 8 with higher value indicating the availability of more credit information.	World Bank Doing Business Database	-	-
Legal right	positive number	Legal right is an index that measures the strengths of minority shareholder protections against misuse of corporate assets by directors for their personal gain as well as shareholders rights, governance safeguards and corporate transparency requirements that reduce the risk of abuse. It ranges from 0 (weak legal rights protection) to 12 (strong legal rights protection).	World Bank Doing Business Database	+	+
Reserve	ratio	Reserve is calculated as the ratio of cash and balances at the central bank on total assets.	Orbis Bank Focus & SNL financial	-/+	-/+
Taxation	ratio	Taxation is computed as the ratio of taxes on operating income	Orbis Bank Focus & SNL financial	-/+	-/+